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MODEL 570 SERIES
MICROWAVE
SWEPT OSCILLATORS

Serial No. _____

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Units, abbreviations and prefixes of the International system of Units (SI) are used in this manual. Discrepancies may be noted between the terms used in the text and the instrument panel markings (e. g. ; hertz, kilohertz, megahertz for cps, kilocycles, megacycles, etc.)

The National Bureau of Standards announced its approval of the SI in February 1964, and subsequently the document was adopted by Congress as a national standard.

WARRANTY

E-H instruments are warranted to be free from defects in material and workmanship for one year. For in-warranty repair of this instrument, contact E-H Research Laboratories, Inc., Customer Service Department and provide:

a. Instrument model number and serial number.
b. Details concerning the nature of the malfunction.

Shipping instructions, or repair information and parts will be sent to you promptly.

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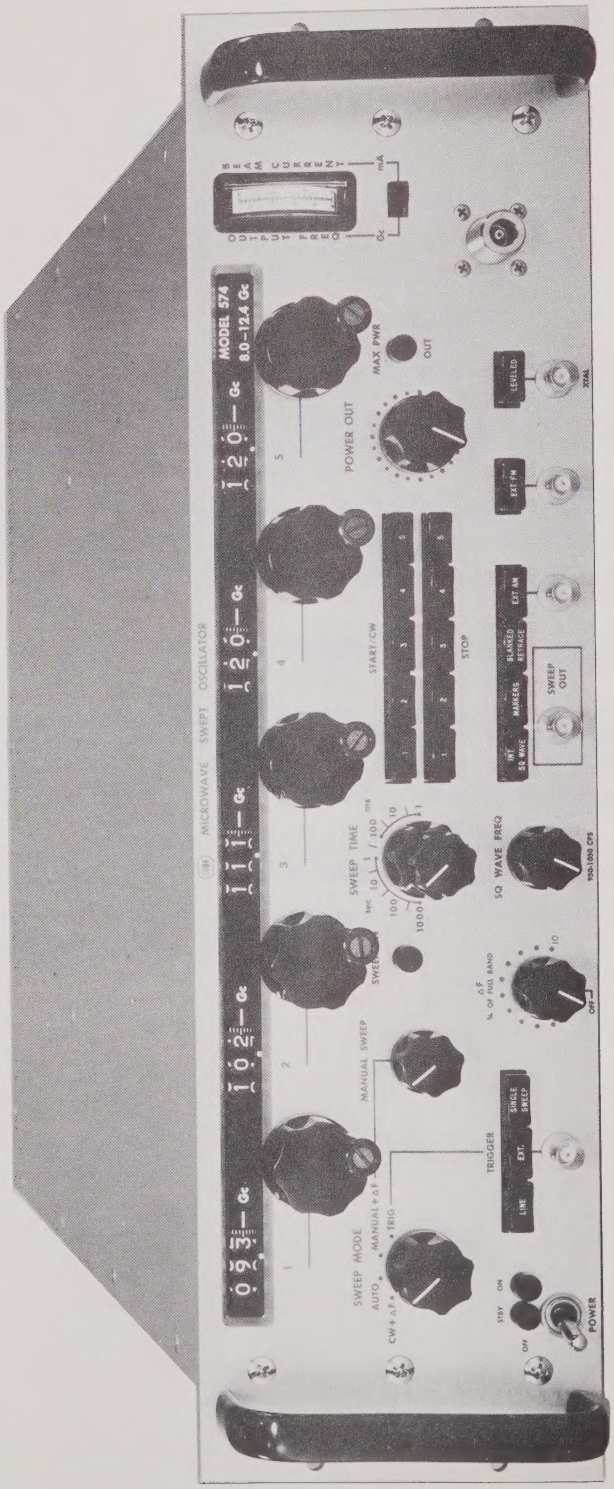


Fig 1-1 MODEL 570 MICROWAVE SWEPT OSCILLATOR

SECTION 1
SPECIFICATIONS

1-1 GENERAL

The E-H Model 570 Series of Microwave Swept Oscillators provides accurate and versatile microwave swept signal sources utilizing a Backward Wave Oscillator Tube. Each instrument in the series covers approximately 1 octave of frequency range (see detailed specifications, Fig 1-2), with full capability to; (a) sweep the output frequency between accurately settable limits, (b) provide panel-controllable frequency markers, and (c) amplitude and/or frequency modulate the microwave output from either internal or external waveforms.

1-2 SPECIFICATIONS

a. Frequency Controls. Five independent controls with 3-digit readout, each continuously adjustable over the entire frequency range.

(1) Frequency Accuracy. Better than 1% at any output power level.

b. SWEEP MODES.

(1) CW + ΔF: Single-frequency output at START/CW frequency selected by pushbutton. Any of the 5 frequency dials may be selected. Δ F sweep may be superimposed.

(2) AUTO. Sweeps from start frequency to stop frequency selected by pushbutton switches. Any of the five frequency dials may be selected as start or stop. Sweep recurs automatically.

(3) MANUAL + ΔF. Front panel control varies the output frequency from START/CW to STOP frequency. ΔF sweep may be superimposed.

(4) TRIG. Trigger initiates sweep from START/CW to STOP frequency. LINE: Internally triggered, synchronous with power line frequency. EXT: triggered by externally applied signal greater than +4V, greater than 1 μs pulse width. SINGLE SWEEP: pushbutton initiates sweep.

c. ΔF Sweep. Sweeps from lower to higher frequency, centered on CW or MANUAL SWEEP setting. Disabled with control fully counterclockwise (OFF position).

(1) Width. Continuously adjustable from zero to 10% of the frequency band.

(2) Width Accuracy. 10% of ΔF being swept ± 1.0% of bandwidth of instrument.

(3) Center Frequency Accuracy. Better than 1% at any power level.

d. Frequency Markers. Up to 5 frequency markers are available. Marker frequencies are determined by those frequency controls not selected as START/CW or STOP. Markers amplitude modulate RF output when front panel MARKERS pushbutton is depressed.

(1) Accuracy. Better than 1% at any power level.

(2) Resolution. Better than 0.05% at any frequency.

(3) Marker Output. +1.0V triangular pulse from 500Ω source impedance at rear panel connector.

e. Residual AM. At least 40 dB below rated CW output.

f. Spurious Signals. Harmonics at least 20 dB below CW output; non-harmonics at least 40 dB below rated CW output.

g. SWEEP TIME. Continuously adjustable in 6 decade ranges, 0.001 to 1000 seconds. Controlled retrace time and dwell times at beginning and end of sweep each approximately equal to 10% of sweep time.

h. SWEEP OUTPUT. Zero to +15V concurrent with swept RF output. Output impedance less than 100Ω in series with 20 μH.

i. REFERENCE OUTPUT. Direct-coupled voltage proportional to RF output frequency. Zero at low end of band, -20V at high end. Output impedance, 4KΩ.

j. FREQUENCY LINEARITY. Better than 1%.

k. BLANKING. Switching occurs at approximate mid-point of dwell times at ends of sweep.

(1) BLANKING OUTPUT. 0V during sweep, -3V during retrace.

(2) BLANKED RETRACE. Front panel pushbutton switch for reducing output power to zero during retrace.

(3) PEN LIFT. Terminals closed during sweep, open during retrace on three slowest sweep time ranges. Contacts open on all other sweep ranges.

l. STOP PULSE. +5V during dwell time at end of sweep; zero otherwise. Output impedance 1KΩ. Can trigger another sweeper to obtain very broad band sweeps.

m. POWER LEVELING AMPLIFIER. Internal direct-coupled leveling amplifier provided.

(1) Crystal Input. Leveler loop is designed for 20 dB coupler (10 dB with 576 and 577) and negative polarity crystal detector. Leveled power variation specification applies for sweep rates up to 10% of full band per millisecond.

(2) Power Meter Input. 1000Ω input resistance and leveler amplifier gain shaping designed for 20 dB coupler (10 dB with 576 and 577) and H-P 431B or PRD 686 power meter or equivalent. Sweep rates must be compatible with response time of power meter.

n. POWER VARIATION, UNLEVELED. Less than 6 dB over the entire band at maximum power out.

o. POWER VARIATION, EXTERNAL LEVELING. ± 0.1 dB + coupler and detector variations at rated output power.

p. EQUIVALENT SOURCE MATCH. Externally leveled: Depends on coupler. Unleveled: Less than 2.5:1.

q. MODULATION.

(1) Internal square wave AM. 100% modulation continuously adjustable in frequency from 950 to 1050 Hz with frequency stability of less than 0.05% per minute after one minute warm up.

(2) External AM.

(2a) Frequency Response. DC to 1 MHz unleveled, dc to 50 kHz leveled.

(2b) Sensitivity. 10V for 100% modulation; -10V at any power setting reduces output power to zero.

(2c) Polarity. Positive voltage increases output power.

(3) External FM.

(3a) Frequency Response. DC to 100 kHz.

(3b) Maximum Range. Full band for modulation frequency up to 1 kHz (20V peak-to-peak input) decreasing to about 1% of full band at 100 kHz.

(3c) Sensitivity. Deviation from internally generated frequency, 5% of band per volt.

(3d) Input Impedance. 4kΩ ± 2%.

r. METER ACCURACY.

(1) Output Frequency. ± 4% of total bandwidth of the instrument.

(2) Beam Current. ± 6% of full scale.

s. FREQUENCY STABILITY.

(1) With Temperature. 0.01%/°C.

(2) With 10% Line Voltage Change. 0.01%.

(3) With Power Level Change. Frequency accuracy specification is maintained.

(4) Residual FM. Less than 10 ppm peak, referred to the total bandwidth of the instrument.

t. POWER. 117V, 50/60 Hz; 234V optional. Approximately 200 volt-amperes.

u. DIMENSIONS. 5-1/4" x 19" x 19".

v. WEIGHT. 55 lbs or less.

w. INSTALLATION. The BWO must be kept at least 4 inches away from any ferromagnetic materials. Strong magnetic fields can also be harmful to the BWO.

Model	571	572	573	574	574-1	575	576	577
Freq Range (GHz)	1-2	2-4	4-8	8.0-12.4	7.0-12.4	12.4-18	18-26.5	26.5-40
Max Pwr Out (mW) (Leveled or Unleveled)	120	90	35	50	30	48	12	6
Residual FM (Peak)	10kHz	20kHz	40kHz	44kHz	54kHz	112kHz	170kHz	270kHz
Output Impedance	50Ω	50Ω	50Ω	50Ω	50Ω	--	--	--
Output Connector	Type N	Type N	Type N	Type N	Type N	UG-419/U	UG-595/U	UG-599/U

Fig 1-2 Detailed Specifications

SECTION 2
OPERATING INFORMATION

2-1 GENERAL

The output of the E-H Model 570 Series Microwave Sweeper can be controlled by the operation of panel-mounted controls, or by externally applied voltages.

The panel-mounted controls permit sweeping any part of, or all of, the instruments frequency range, with a wide choice of sweep rates. The frequency can be swept between two accurately set limits (START/CW and STOP), or can be swept around an accurately set center frequency (ΔF, % of Full Band). The power output can be manually adjusted by the POWER OUT control, externally leveled by either a crystal detector or a power meter, or can be chopped by an internal squarewave generator.

In addition to panel-mounted controls, inputs are provided for controlling output frequency and power output by externally applied voltages.

2-2 FUNCTION OF FRONT PANEL CONTROLS AND CONNECTORS

a. POWER. A three-position switch which controls primary power to the instrument. In STBY, heater voltage is applied to the BWO and the low voltage supplies energize the control circuitry of the instrument; there is no RF output. If switched ON from a cold start, STBY operation occurs for a 45 second warm-up period, after which full primary power is applied. After the initial STBY warm-up period has elapsed, power output from the BWO is available immediately when the switch is placed in the ON position. The associated lights indicate whether the instrument is in STBY or ON.

b. FREQUENCY DIALS. The five 3-digit frequency dials control the swept-frequency limits, CW output frequency, center frequency for ΔF, and marker frequencies; depending on the functions selected by the SWEEP MODE switch and the START/CW - STOP pushbuttons. Each of the five frequency dials covers the full frequency range of the instrument. The five dials are completely interchangeable, in that any dial can be selected to perform any of the dial functions. Any frequency dial not selected as START/CW or STOP becomes a frequency marker dial.

The swept frequency direction may be from high to low, or low to high, depending on whether the selected START/CW frequency is higher or lower than the selected STOP frequency. There are no forbidden combinations for setting the frequency dials or selecting the functions they are to perform. The function selections may be changed without disturbing the frequency dial settings. This makes it possible to switch back to a previous set-up without having to re-position the frequency dials.

c. START/CW. Five numbered pushbuttons, one corresponding to each of the five frequency dials. Selects which frequency dial will determine the start frequency in AUTO, TRIG, and MANUAL positions of the SWEEP MODE switch. In the CW position of the SWEEP MODE switch, selects which frequency dial will determine the CW frequency.

d. STOP. Five numbered pushbuttons, one corresponding to each of the five frequency dials. Selects which frequency dial will determine the stop frequency in AUTO, TRIG, and MANUAL positions of the SWEEP MODE switch. In the CW position of the SWEEP MODE switch, the STOP pushbutton has no effect.

e. SWEEP MODE. Selects either the CW mode, or one of three swept frequency modes.

(1) AUTO. The frequency continuously sweeps back and forth between the start and the stop frequency. The time required to sweep from the start to the stop frequency is determined by the SWEEP TIME control. The retrace (from the stop frequency back to the start frequency) is 10 times faster. Output power may be inhibited during retrace (see BLANKED RETRACE).

(2) TRIG. Same as described above for AUTO, except that each sweep must be initiated by a trigger (see TRIGGER pushbuttons).

(3) MANUAL + ΔF. The output frequency can be swept between the start and the stop frequency with the MANUAL SWEEP control.

(4) CW + ΔF. The frequency dial selected as the START/CW dial determines the output frequency.

f. TRIGGER. Three pushbuttons which select the triggering source when the SWEEP MODE switch is in the TRIG position.

(1) LINE. The sweep is triggered internally from the power-line frequency.

(2) EXT. The sweep is triggered by an externally applied signal of at least +4 volts amplitude and not less than 1μs pulse width.

(3) SINGLE SWEEP. Depressing the momentary-contact SINGLE SWEEP button after completion of a sweep initiates a new sweep. The sweep generator free-runs if the SINGLE SWEEP button is held down.

g. MANUAL SWEEP. When the SWEEP MODE switch is in the MANUAL + ΔF position, the MANUAL SWEEP control replaces the internal sweep generator. The output frequency can be manually swept between the start frequency (CCW) and the stop frequency (CW). ΔF and EXT FM can be superimposed.

h. ΔF, % OF FULL BAND. When switched ON, provides a recurrent swept frequency up to 10% of the frequency range of the instrument. The center frequency for the ΔF mode is determined by the START/CW dial in the CW + ΔF mode, and by the MANUAL SWEEP control in the MANUAL + ΔF mode. The sweep time is set by the front-panel SWEEP TIME control. The SWEEP OUT voltage sweeps from 0 to +15 volts concurrent with the swept ΔF.

i. SWEEP ON. The SWEEP ON light indicates that the internal sweep generator is running in the forward direction. The light functions in any of internally swept modes: AUTO, TRIG, or ΔF. In the triggered mode, the light turns on as soon as the trigger has been received, but before the output frequency actually starts sweeping.

j. SWEEP TIME. A six position decade switch and a concentric vernier provide sweep times from 1 ms to 1000 seconds in six overlapping decade ranges. The dwell times at the ends of the sweep and the controlled retrace are each approximately 10% as long as the selected sweep.

k. SWEEP OUT. Provides a 0 to +15 volt sawtooth, emitter-follower isolated from the internal sweep generator in any of the internally swept modes; or from the MANUAL SWEEP control in the MANUAL mode. The output voltage is proportional to the frequency actually being swept. In the AUTO or TRIG modes, 0 volts corresponds to the START frequency and +15 volts corresponds to the STOP frequency. In the ΔF modes, 0 volts corresponds to the low frequency limit of the sweep and +15 volts corresponds to the high frequency limit of the sweep.

l. SQ WAVE FREQ. Adjusts the repetition rate of the internally generated square wave between the limits of 950 and 1050 Hz.

m. AMPLITUDE MODULATION PUSHBUTTONS. Four pushbuttons which select the amplitude modulation to be applied to the RF output.

(1) INT. SQ. WAVE. Turns on the internal square wave generator and switches the RF power output between 0 and the power output level selected by the remainder of the amplitude controls and inputs.

(2) MARKERS. When depressed, amplitude modulates the RF output at the marker frequencies. Marker frequencies are set by those frequency dials not selected as START/CW or STOP dials.

(3) BLANKED RETRACE. When depressed, turns off the RF output power during the sweep retrace. Switching occurs near the mid-points of the start and stop dwell times.

(4) EXT. AM. When depressed, allows amplitude modulation from an external signal applied to the associated connector. Bandwidth is dc to 1 MHz unleveled, or dc to 50 kHz crystal leveled. A 10 volt peak-to-peak signal will modulate the power output between off and full on. Input impedance is 100 K.

n. EXT. FM. When depressed, allows frequency modulation from an external signal applied to the associated connector. External FM bandwidth is from dc to 100 kHz. External FM is superimposed on whatever output frequencies are internally selected. Input impedance is 4 k, a plus voltage increases frequency and a minus voltage decreases frequency. A 20 volt peak-to-peak signal will modulate the output frequency over the full range of the instrument. Maximum Range; full band at 1 kHz, decreasing to 1% of the band at 100 kHz.

o. POWER OUT. A manual control to adjust the RF output, from 0 to maximum, in either leveled or unleveled operation. All other amplitude modulation is superimposed on this level.

p. MAX PWR OUT. This light turns on when the RF output is at the maximum available power level. In unleveled operation this corresponds to full clockwise rotation of the POWER OUT control. In leveled operation, the light indicates that the summation of the amplitude controlling inputs are asking for power in excess of the maximum available power. When the light is on, leveling is not being accomplished at the maximum power level. The POWER OUT control should be reduced so the light does not come on.

q. LEVELED. When depressed, allows closed-loop external leveling at the load with a 20 dB directional coupler (10 dB for Model 576 and 577) and a negative-output crystal detector or thermistor-mount powermeter, whichever is selected by the rear-mounted LEVEL DETECTOR switch.

The associated connector, marked XTAL, is used for crystal detectors only. When using a power meter, the input must be applied to the rear-mounted connector, labeled POWER METER.

r. METER. Can be selected to indicate either output frequency or BWO beam (cathode) current in CW or slowly swept operation. For faster sweeps, average value is indicated.

s. RF OUTPUT. Type N female connector or waveguide and cover flange deliver RF output to the load.

2-3 FUNCTION OF REAR PANEL CONTROLS AND CONNECTORS

a. TRIGGER INPUT. Wired in parallel with the

front panel-mounted TRIGGER INPUT connector for cabling convenience in system and cascade-sweeper applications.

b. STOP PULSE OUTPUT. A +5 volt pulse during the stop dwell time. May be used to trigger a cascaded sweeper for multi-band sweeps.

c. BLANKING OUTPUT. A -3 volt level during the blanking interval whether or not the front-panel BLANKED RETRACE button is depressed. Switching occurs near the midpoint of the start and stop dwell times.

d. MARKER OUTPUT. Triangular pulses of approximately +1 volt amplitude when the output frequency crosses a marker frequency whether or not the front panel MARKERS button is depressed.

e. REFERENCE OUTPUT. An output voltage proportional to the RF output frequency. When the output frequency is at the instruments low frequency limit, the REFERENCE output is 0 volts. When the output frequency is at the high frequency limit, the REFERENCE output is -20 volts. Source impedance is 4 k-ohms.

f. LEVEL DETECTOR SWITCH. Selects crystal or power-meter detector for leveling. The input connector for power-meter leveling is directly below the switch. The 1 k termination necessary for proper power-meter operation is built into the sweeper. The LEVEL DETECTOR switch must be in the position corresponding to the level detector used. The input for crystal level detector is on the front panel.

g. PEN LIFT Connectors. For X-Y recorder operation, these two terminals are connected together during sweep time and open during retrace blanking time on the three slowest sweep ranges. On all other sweep ranges, the contacts remain open all the time.

2-4 OPERATION

a. SWEPT OPERATION. The Model 570 Series Microwave Sweepers have four sweep modes; AUTO, CW, MANUAL and TRIGGERED.

For wide-band sweeps, the AUTO or TRIG modes are used. For narrow sweeps, the ΔF, % of Full Band control provides a symmetrical sweep up to 10% of the full frequency range of the instrument centered on the MANUAL SWEEP frequency or the frequency determined by the FREQUENCY DIAL selected as the START/CW dial.

In the AUTO mode, the output frequency is recurrently swept back and forth between the START/CW frequency and the STOP frequency by the internal sweep generator. The sweep time in the forward direction (between START/CW and STOP) is selectable by the SWEEP TIME control from 1 millisecond to 1000 seconds. The relationship between sweep time, dwell time, retrace time, etc. are shown in Fig 2-1.

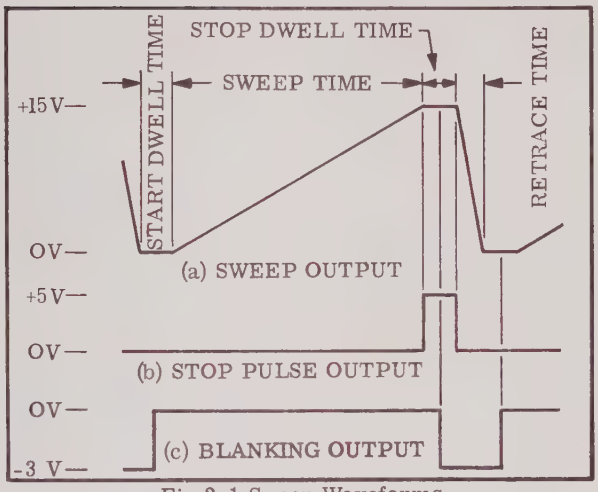


Fig 2-1 Sweep Waveforms

In the TRIG mode, operation is similar except that a trigger signal is required to initiate each sweep. Three trigger pushbutton switches select the triggering source.

(1) For LINE triggering, the sweep generator is internally triggered from the power-line frequency. Since the SWEEP TIME and TRIGGER controls are separate, the LINE trigger may be used with any sweep time. Trigger signals received during a sweep are disregarded.

(2) External triggering requires a +4 volt signal (of at least 1 μs duration) at either the front or rear panel TRIGGER INPUT connectors. The EXTERNAL triggering mode can also serve as a gate, in that the sweep will free-run as long as the TRIGGER INPUT is held above +4 volts.

(3) The SINGLE SWEEP function triggers the sweep each time the SINGLE SWEEP button is depressed. As long as the SINGLE SWEEP button is held down, the sweep will free-run.

In the MANUAL mode, the output frequency may be manually swept from the START/CW frequency to the STOP frequency. The counterclockwise extreme of the MANUAL SWEEP control corresponds to the START/CW frequency, and the clockwise extreme corresponds to the STOP frequency. The MANUAL sweep mode is particularly useful in reducing recorder set-up time.

In the CW mode, the output frequency is determined by the frequency dial selected as the START/CW dial, and is independent of the STOP frequency. Any one of the five frequency dials may be selected as the START/CW dial.

The ΔF function provides narrow-band sweeps of up to 10% of the full range of the instrument. In the MANUAL + ΔF mode, the MANUAL SWEEP control can be used to scan the frequency range from the START/CW frequency to the STOP frequency. The ΔF control can then be used to display a narrow range of frequencies around any particular area of interest. Or, the ΔF may be switched on first and a

narrow frequency window scanned across the START/CW to STOP frequency range. This magnifies the ΔF portion of the START/CW to STOP frequency range to the full oscilloscope or recorder display size. Because the ΔF is a separate control, none of the five frequency dial settings need be disturbed during ΔF operation.

b. MARKERS. Each of the FREQUENCY DIALS not selected as the START/CW or the STOP dial defines a marker frequency. As the BWO output frequency crosses any of these defined frequencies a marker is generated. Markers may be used to bracket a frequency range of interest and then be selected as the new sweep limits for more detailed examination, without disturbing the previous sweep limits. The vee-shaped markers are large enough to be clearly visible with wide sweeps, yet narrow enough to give excellent resolution on extremely narrow sweeps.

c. SWEEP WAVEFORMS. Sweep time is continuously adjustable with the SWEEP TIME selector switch and its associated vernier control over the range of 1 millisecond to 1000 seconds. This permits making extremely precise, slowly-swept measurements, or very fast sweep rates such as are needed in sweep radar studies. The SWEEP OUTPUT voltage changes from 0 to +15 volts while the output frequency is swept from the START/CW frequency to the STOP frequency, independent of the frequency range being swept or the direction of the frequency sweep. The sweep voltage waveform is shown in Fig 2-1, and is available at the SWEEP OUT connector.

To allow other components in the swept measurement system (e.g. detectors, recorders, etc.) sufficient settling time, there are dwell times at the beginning and end of each sweep, and a controlled retrace time. Each is equal to approximately 10% of the sweep time. The blanking interval starts near the mid-point of the stop dwell-time and lasts till the midpoint of the start dwell-time, as shown in Fig 2-1. When the BLANKED RETRACE pushbutton is depressed on the front panel, the RF power output is turned off during the retrace interval. The blanking signal is available for use by external equipment at the BLANKING OUTPUT jack, J305.

On the three slowest SWEEP TIME ranges, the PEN LIFT terminals provide a switch closure during sweep time. The terminals are open during the retrace interval. The terminals remain open all the time on all sweep ranges except the three slowest.

The STOP PULSE output (see Fig 2-1) provides a +5 volt pulse during the stop dwell-time at the end of the sweep. This waveform may be used to trigger another Model 570 sweeper for two-band sweeps. Cascade triggering of several Model 570 sweepers will provide multi-band sweeps.

d. LEVELING. The Model 570 Series Microwave Sweepers are capable of external closed-loop leveling at the load to provide constant power over the frequency range even when the inter-connecting signal plumbing does not have a flat frequency response. The internal leveler amplifier holds leveled power at the sensing point to ± 0.1 dB, excluding coupler and detector variations. The leveler amplifier accepts feedback from a 20 dB coupler (10 dB for Models 576 and 577) and either a negative-output crystal detector or a microwave power meter (PRD 686 or H-P 431B, or equivalent). Because of the relatively slow response time of power meters, power-meter leveling must be used with compatible sweep times (typically 30 seconds or longer). For applications where external couplers and detectors would be undesirable, internal leveling is available as an optional extra. Consult your E-H representative or the factory for exact details.

Internal open-loop leveling, through anode programming, is a feature in each of the Model 570 Series Microwave Sweepers. This internal programming holds the power variation across the frequency range within 6 dB maximum, typically 3 dB. In many applications this degree of leveling is adequate and eliminates the need for additional leveling components.

e. MODULATION. Push-button modulation-selection switches provides for flexibility in both amplitude and frequency modulation of the RF power output from the Model 570 Series sweepers. Frequency modulation in accordance with an externally-applied dc to 100 kHz signal may be superimposed on any internally swept or CW mode.

This feature allows a wide variety of predictable control over the output frequency of the instrument. In addition to complete internal control by the manipulation of panel knobs and dials, the output frequency can be programmed by an externally applied voltage waveform or complex combinations of both internal and external control.

Any or all of the four amplitude modulation functions may be performed simultaneously.

(1) The internal square-wave generator, when selected, switches the output power from completely off to the power level selected by the POWER OUT control. The square-wave frequency is variable by a front panel control from 950 to 1050 Hz.

(2) The frequency markers amplitude modulate the RF power output if the MARKERS button is depressed.

(3) RF power output is turned completely off during the blanking interval of the internally generated sweep if the BLANKED RETRACE button is depressed. See Fig 2-1 for timing relationship.

(4) External AM provides the ability to control the output power of the instrument with an externally-applied voltage waveform. A positive voltage at the EXTERNAL AM jack increases the power output, a negative voltage decreases power output. With the panel-mounted POWER OUT setting at full power, -10 volts at the EXTERNAL AM jack will completely turn off the power output. Conversely, with the POWER OUT setting at 0, +10 volts will turn on full power.

SECTION 3
THEORY OF OPERATION

3-1 GENERAL

This section of the manual contains an electrical description of each circuit in the Model 570 Series Microwave Swept Oscillators. A block diagram is included in the drawings section showing the overall realtionship of the various circuits. Schematic circuit numbers are used to identify components in the circuit descriptions. Refer to the specific schematics in the drawing section to suppliment the following discussion.

The Model 570 Series Microwave Sweepers provide closely controlled voltages and waveforms to an internally-mounted Backward Wave Oscillator Tube (BWO). The BWO in turn produces a predictable RF output, with the output power and the output frequency being functions of the voltages and waveforms applied to the BWO.

A comprehensive thesis on BWO theory is beyond the scope of this instruction manual. However, since the operation and adjustment of the circuits in the Model 570 are dictated by the unique characteristics of the BWO, the following fundamental discussion might prove useful in the periodic maintenance and recalibration of the instrument. Refer to the generally available text material for more complete details on BWO theory.

The backward wave oscillator tube consists of (1) an electron-gun structure, (2) a spiral helix element, and (3) a collector. For the purposes of this discussion it can be considered to be a "black box" which generates an RF signal, both the power output and the frequency being voltage-controllable. See Fig 3-1.

(1) The electron-gun structure includes the cathode, control grid, anode, and the focusing magnets. It provides a focused electron beam which travels down the longitudinal axis of the helix to the collector. The beam current is determined by the voltages applied to the control grid and the anode, similar to the control grid and the screen grid of a conventional pentode.

(2) The helix and the voltage applied to it are the frequency determining elements. The RF power output is coupled from one end of the helix.

(3) The collector is held at a constant voltage relative to the helix and serves only as a collector for the electron beam after it has passed through the helix.

The theoretical basis for the operation of a BWO is closely related to a traveling wave amplifier tube, the distinction between the two being quantitative design parameters. The microwave oscillations in a BWO depend on the mutual interchange of energy between the accelerating helix element inside the tube and an electron beam traveling in close proximity to the helix and along its longitudenal axis.

Oscillations in the helix cause velocity modulation of the beam electrons adjacent to each of the helix windings as they travel down the tube towards the collector. The resulting acceleration and deceleration of electrons as they pass each helix winding provides the mutual interchange of energy between the oscillations in the helix and the electron beam. A wave moves along the helix in a direction opposite to the electron beam, hence the term backward wave oscillator.

Practical BWOs have a voltage-controllable frequency

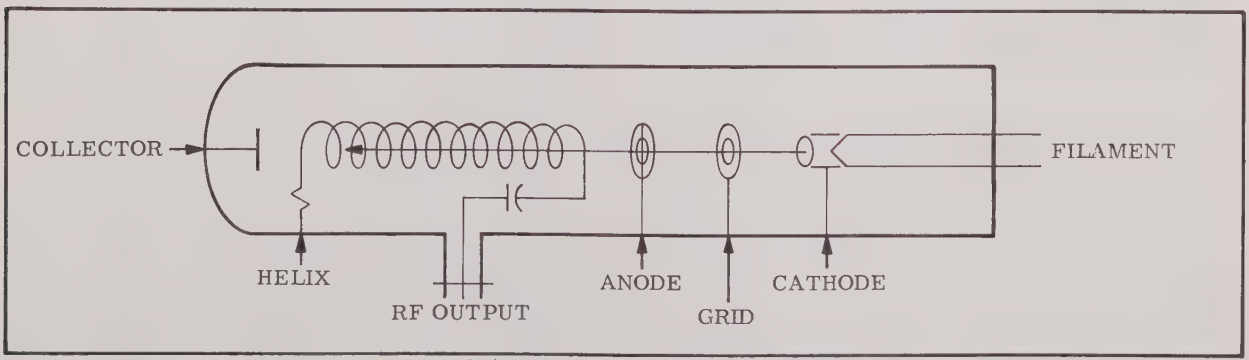


Fig 3-1 Backward Wave Oscillator Tube

range in the order of 1 to 2 octaves. Several of the operating parameters of the BWO depend on the ratio of helix circumference to the free-space wavelength of the oscillations. Since the circumference of the helix is fixed in a specific BWO, the ratio is practically determined by the frequency of oscillation.

At the long wavelength end of the frequency range, the coupling impedance of the BWO drops below a practical limit. At the short wavelength end of the frequency range, there are frequencies where the helix does not operate in the backward wave mode, resulting in holes in the power output curve. However, there is a wide range of frequencies over which the BWO output is predictable. The Model 570 Series Sweepers operate over a frequency range of about 1 octave and well within the predictable range of their specific BWOs.

The frequency of oscillations in the helix is primarily a function of the mean velocity of the beam electrons through the helix. Electron velocity, in turn, is a function of the accelerating voltage applied to the helix. However, as second order effects, frequency is influenced by beam density, beam current, focus, proximity of the beam to the helix, etc. These second order effects result in frequency pushing with changes in beam current, and frequency modulation by unregulated supply voltages or heater voltage fluctuations. Ideally, frequency should be solely a function of helix voltage, but such is not the case. The Model 570 Series Sweepers compensate for undesirable second order effects, and the output frequency is accurately predictable.

The power transferred from the electron beam to the helix is a function of both electron velocity and total number of beam electrons (beam current). Since electron velocity is also one of the factors in determining power output, there is an unavoidable relationship between voltage-controlled frequency and power output in an uncompensated system. The voltage on the control grid of the BWO offers the best opportunity to control power, independent of frequency, in that the grid has control over beam current and only has a small effect on electron velocity. The anode, like the control grid, is a beam-current controlling element, and as such can be used to control output power. In addition to being a beam-current controlling element, the anode also effectively shields the cathode from changes in helix voltage. Otherwise, beam current (and consequently, power output) would change greatly from the low to the high edge of the frequency range as a result of the change in helix voltage.

In the Model 570 Series Sweepers, the anode voltage is programmed as an inverse function of helix voltage so that relatively high beam current is provided at the low electron-velocity end of the frequency range (low frequency end), and less beam current is provided at the high electron-velocity end of the frequency range. This anode programming results in nearly constant power output over the full frequency range of the instrument without closed-loop leveling.

Since the inherent characteristics of the BWO require a somewhat complex set of cross compensations between the power-controlling circuits and the frequency-controlling circuits, it is important to observe the proper sequence of adjustments during maintenance and recalibration of the instrument.

3-2 BLOCK DIAGRAM

a. SWEEP GENERATOR. The sweep generator is a Miller-integrator. It produces a positive going linear sawtooth of voltage from 0 to +20 volts and then retraces to 0 in 1/10th the run-up time. Its normal mode of operation is free-running. The time interval of a complete cycle of waveform (run-up and retrace) is determined by the panel-mounted SWEEP TIME selector switch.

In the triggered mode of operation, the trigger circuit catches and holds the sweep generator at its most negative excursion (0 volts output). Coincident with a trigger input, the sweep is released to free-run. Trigger inputs received while a sweep is in progress have no effect.

b. SWEEP INVERTER. The sweep inverter is an X1 operational amplifier centered around +10 volts. The input to the sweep inverter is the 0 to +20 volt sawtooth output from the sweep generator. The output from the sweep inverter is a negative going sawtooth from +20 to 0 volts.

c. DIAL SELECTOR SWITCHING. The five frequency dials operate independently over the entire frequency range of the instrument. Any one of them can be selected to; determine the START/CW frequency, determine the STOP frequency, provide a marker at a specific frequency, establish the center frequency for the ΔF mode, or determine the center frequency for the external FM mode. Any dial not selected as a START/CW dial or a STOP dial is available to define a frequency marker. The dials can be operated in any combination. In the swept frequency mode of operation, the output can be swept from low-to-high, or high-to-low over any part or all of the frequency range.

d. START FREQUENCY DIAL. In the "AUTO" and "TRIG" position of the SWEEP MODE switch, the dial selected to determine the start frequency is driven by the output of the sweep inverter, a negative going sawtooth from +20 to 0 volts. A specific portion of this applied sawtooth is picked off depending on the setting of the dial and fed to the start follower. When the dial is at the ccw extreme (low frequency end), the arm of the pot is at ground. Therefore, the output from the start dial is a negative going sawtooth, starting at some voltage between 0 and +20 volts depending on the setting of the dial, and progressing to 0 volts at the end of the sweep in any case. The start dial selects a voltage at the beginning of the sweep, but the output from the start dial is always 0 at the end of the sweep regardless of the dial setting

e. STOP FREQUENCY DIAL. In the "AUTO" and

"TRIG" position of the SWEEP MODE switch, the dial selected to determine the stop frequency is driven from the output of the sweep generator, a positive going sawtooth from 0 to +20 volts. Similar to the start dial, a specific portion of this applied sawtooth is picked off depending on the setting of the dial and fed to the stop follower. When the dial is at the ccw extreme (low frequency end), the arm of the pot is at ground. Therefore, the output of the stop dial is a positive going sawtooth starting at 0 and progressing to some voltage between 0 and +20 volts depending on the setting of the dial. The output from the stop dial starts at 0 volts at the beginning of the sweep regardless of the setting of the dial. The stop dial selects only the level at the end of the sweep.

f. START AND STOP FOLLOWERS. The start and stop followers are two separate but identical bootstrapped emitter followers. The voltage output from each of the followers is identical to its own input. The purpose of the followers is to drive the summing amplifier with the voltages from the start and stop dials but from a constant source impedance. If the summing amplifier were driven directly by the start and stop dials, the source impedance would be a function of the dial setting.

g. SUMMING AMPLIFIER. The summing amplifier is a multi-input operational amplifier with a gain of -1. The output of the summing amplifier is limited to 0 to -20 volts. The inputs to the summing amplifier are; (1) the start follower, (2) the stop follower, (3) ΔF, % of Full Band, and (4) Ext. FM jack, J204. Providing the output limits are not exceeded, the output is the sum of the inputs, only inverted.

The input from the start follower is a selected voltage at the start of the sweep, progressing linearly to 0 at the end of the sweep. The output from the stop follower is 0 at the start of the sweep progressing linearly to a selected voltage at the end of the sweep. The output of the summing amplifier, as a result of these two inputs, is a voltage that starts at a level determined by the start dial at the beginning of the sweep and linearly progresses to a level determined by the stop dial at the end of the sweep.

h. SWEEP AMPLIFIER AND HELIX DRIVER. The sweep amplifier together with the helix driver constitute an operational amplifier that drives the helix and collector of the BWO in accordance with the frequency determining sawtooth.

The input to the sweep amplifier is the 0 to -20 volt output from the summing amplifier. There is also a correcting input to the sweep amplifier from the leveler amplifier to compensate for frequency pushing when the grid level of the BWO is changed.

The feedback around the operational amplifier contains an adjustable non-linear network of 10 potentiometers and diodes such that the exact waveform applied to the helix can be compensated to produce the output frequency called for by the output of the summing amplifier.

i. HELIX OVER-CURRENT DETECTOR. The helix over-current detector is a current-sensitive self-latching relay system which removes power from the BWO if the helix current exceeds a specified value.

j. ANODE REGULATOR. The anode regulator is a programmed amplifier which drives the anode of the BWO in accordance with the output frequency being called for by the summing amplifier. The regulator contains "min" and "max" limit adjustments and a slope gain control. The anode regulator applies more voltage to the BWO anode at the low frequency end than at the high frequency end to compensate for the inherent low power output of the BWO at low frequencies.

k. LEVELER AMPLIFIER. The leveler amplifier controls the beam current through the BWO by determining the control-grid voltage. The leveler amplifier is a multi-input operational amplifier. It's inputs are; (1) the panel-mounted POWER OUT control, (2) the input from the external crystal level detector (or power meter), (3) the external AM input, (4) the blanked retrace waveform from the sweep generator, (5) markers from the frequency dials not used as start or stop, (6) the internal squarewave waveform, and (7) the output waveform from the summing amplifier.

The output of the leveler amplifier is limited at the maximum power end. If the combined effect of all the inputs reaches the max power limit, the leveler amplifier turns on the panel-mounted MAX PWR OUT light. This condition indicates that the BWO cannot respond to the power called for by the summation of the inputs.

An output from the leveler amplifier drives the BWO control-grid. Another output from the leveler amplifier supplies a sample of the BWO control-grid voltage to the sweep amplifier to compensate for frequency pushing as a function of changes in beam current.

l. MARKER GENERATOR. The marker generator is made up of five amplitude-coincidence discriminators (one for each of the five frequency dials) and one common output stage. Each of the five discriminators receives a dc level input between 0 and -20 volts from its respective frequency dial if the dial is not selected as a start or stop dial. Each of the discriminators also receives the output of the summing amplifier (0 to -20 volts). When the output of the summing amplifier is amplitude coincident with the dc level selected by any of the five frequency dials, the respective discriminator produces a marker output through the common output stage.

The discriminator input level from the dial selected as the start dial and the one selected as the stop dial is a plus voltage. Since the output from the summing amplifier is limited to the range from 0 to -20 volts, coincidence cannot occur and no marker is produced by the start or the stop dial.

An output from the marker generator is applied to the input to the leveler amplifier to cause the output power from the BWO to be reduced as the output frequency

crosses the frequency selected by the marker dial (providing the panel-mounted marker switch has been selected).

Another output from the marker generator is present at a rear-mounted connector, MARKER OUTPUT J306, whether the panel-mounted marker switch is selected or not.

m. PEN LIFT CIRCUIT. The pen lift circuit provides a contact closure brought out to two binding posts mounted on the rear panel. The contacts close during sweep time on the three longest (CCW) positions of the SWEEP TIME switch.

n. SWEEP OUTPUT AMPLIFIER. The sweep output amplifier provides a 0 to +15 volt output for external use. The output voltage is dependent on the position of the SWEEP MODE switch. In the "AUTO" and "TRIG" positions, the output is proportional to the sweep generator outout. In the "CW" position, the output is 0. In the "MANUAL" position, the output is proportional to the position of the MANUAL SWEEP control.

o. OUTPUT FREQUENCY METER. The panel-mounted output frequency meter reads either (a) beam current through the BWO or (b) output frequency of the BWO depending on the position of its selector switch.

p. FILAMENT REGULATOR AND FILAMENT OVER VOLTAGE DETECTOR. The filament regulator and over voltage detector regulates the BWO heater voltage, and operates a self-latching relay system which removes power from the BWO if the heater voltage becomes excessive.

3-3 CIRCUIT DESCRIPTION

a. SWEEP GENERATOR. The sweep generator is an adaptation of a Miller-integrator sawtooth generator. It generates a sawtooth of voltage in either direction between the limits of -2 and +22 volts, depending on the state of the sweep gating multivibrator. The sweep generator consists of V1, Q1, and Q9 together with their associated components.

The timing capacitor is C8, paralleled by C201 through C206 depending on the SWEEP TIME selected. To produce a linear sawtooth of voltage across C8, it is necessary to provide a constant charging current through it. R30 provides the charging current during the run-up. As long as the voltage across R30 is constant, the current through it will be constant, and the voltage across C8 will run up as a linear function of time.

R33 provides the discharge current for C8, and the same general requirements hold true. As long as the voltage across R33 remains constant, the current through it will be constant and the voltage across C8 will run down as a linear function of time. Since the current through R33 is 10 times greater than through R30, the run-down slope will be 10 times faster than the run-up slope.

During the positive-going portion of the sawtooth, the collector of Q10 (sweep gating multi) is negative approximately 4 volts. Current flow for R33 is provided by CR20 and the junction of CR19 and CR20 is far enough negative to back bias CR19. Charging current for C8 is from the -25 volt supply, through R203A, R31, R30, C8, Q1, and R1 to the +25 volt supply. Without the gain and feedback action of V1, Q1, and Q9; this charging current would pull the grid of V1 in a negative direction as C8 charged and reduce the voltage drop across R30 resulting in a typical exponential charge rate for C8. The action of V1, Q1, and Q9 holds the grid of V1 at a very nearly constant voltage, maintaining a constant voltage drop across R30, and insuring a linear run-up for C8.

The mean current flow through V1, Q1, and Q9 is approximately 5 ma through each one of them. Q9 is a constant-current source. The zener diode CR21 and R36 hold the base of Q9 at a fixed -3.3 volts. With the additional emitter-base junction drop of Q9, this establishes 21 volts across R35 and results in a constant current of 5 ma through Q9. It is not important that the current through Q9 be exactly 5 ma, only that it be constant.

Q1 is a grounded base amplifier. Its base is held at +23.4 volts by the divider, R4, CR1, and R3. This voltage together with the emitter-base junction drop of Q1 places 1 volt across R1, making it a constant-current source of 10 ma. The 10 ma supplied by R1 is shared as plate current for V1 and emitter current for Q1. V1 takes a portion of the constant-current 10 ma dictated by its own control-grid voltage, and Q1 conducts the remainder. Thus the conduction through V1 determines the conduction of Q1.

As the charging current through R30 pulls the grid of V1 in a negative direction, conduction through V1 is reduced from its mean of 5 ma. Since R1 is a constant-current source, reduction in plate current in V1 causes Q1 to conduct more than its mean of 5 ma. Increased conduction in Q1 pulls the top of C8 up. Through this action, Q1 pulls the top of C8 up as C8 charges, maintaining the bottom of C8 and the grid of V1 at a very nearly constant voltage. The purpose of Q9 is to provide a 5 ma bias current for Q1 to work against. When Q1 conducts more than 5 ma the collector of Q1 pulls in a positive direction. When Q1 conducts less than 5 ma the collector of Q1 is pulled negative by the 5 ma from Q9.

When the sweep gating multi switches states, the collector of Q10 is near ground. CR20 is backbiased, and CR19 supplies current to R33. The action of the sweep generator is the same as described above except that R33 conducts 10 times as much current as R30, and it is returned to a + supply. The sweep generator run-down is at a slope 10 times faster than the run-up.

The VERNIER control, R203, determines the effective

supply voltages for R30 and R33, and therefore controls the current through them. Since the current through R30 and R33 is the charge and discharge current for the sweep timing capacitor, R203 provides variable control of the slope of the sawtooth.

b. SWEEP-GATING MULTI. The sweep-gating multi is a bi-stable multivibrator. It controls the slope polarity of the output sawtooth from the sweep generator. When the sweep gating multi is in one state the sawtooth runs up, when it is in the other state, the sawtooth runs down.

The sweep-gating multi is made up of Q10 and Q11 together with its switching circuitry, Q3, CR3, CR4, CR5, CR6, CR22, and CR28.

Q10 and Q11 are cross connected in a typical saturating bi-stable multivibrator configuration. The base current path for each of them is through the collector load resistor of the other. The two states of the sweep-gating multi are; (1) Q10 saturated with its collector near ground and Q11 turned off with its collector at -4 volts, or (2) Q11 saturated with its collector near ground and Q10 turned off with its collector at -4 volts. The multi will remain in either state indefinately until it is switched to the alternate state.

The collector voltage of Q10 determines the slope polarity of the sawtooth output from the sweep generator. When Q10 is turned off, its collector is at -4 volts. Current flow through R41 and CR20 satisfies R33 and CR19 is back biased. When Q10 is conducting, its collector is near ground, CR20 is back biased, and R33 provides discharge current to C8. Therefore, when Q10 is conducting the sawtooth is running down (negative slope). When Q11 is conducting, the sawtooth is running up (positive slope).

The sweep-gating multi is normally switched by current flow through CR5 when the sweep has reached its negative extreme, and by current flow through CR3 when the sawtooth has reached its positive extreme.

The sweep plus-limit transistor, Q3 is normally not conducting since its base and emitter are returned to the same point. The voltage at the base of Q3 is established at slightly more positive than +20 volts by the divider, R9 and R10. When the sawtooth is running up (positive slope), Q11 in the sweep-gating multi is conducting. Before Q3 can conduct, the sawtooth must go far enough positive to overcome two junction drops above the reference voltage at the base of Q3. When the sawtooth reaches about +22 volts, CR22 provides emitter current and Q3 conducts as a common base amplifier. Collector current from Q3 pulls up the base of Q11 turning it off and switching the sweep gating multi to the alternate state; that is, Q10 conducting and Q11 turned off. Thus the positive limit of the sawtooth is established at +22 volts.

When the sweep is running down (negative slope), Q10 is conducting and Q11 is turned off. The quiescent condition of the divider, R43-CR6-R36, is with CR6 conducting the 0.5 ma furnished by R43 from the -25 volt supply, and CR4 conducting the remainder of the 0.7 ma required by R12 to the +25 volt supply. Conduction of CR4 holds the anodes of both CR4 and CR6 to not more than one junction drop above ground. As the sawtooth goes more negative than ground, CR5 furnishes the current normally supplied by CR4 and CR6 is pulled negative. The cathode of CR26 is now the same voltage as the cathode of CR5 (the sawtooth voltage) since they are both conducting, and their anodes are tied together. To get Q11 to conduct, the cathode of CR6 must go three junction drops negative. That is; CR22, CR28, and the emitter-base junction of Q11. When the sawtooth reaches about -2 volts, the junction drops are satisfied, Q11 conducts, the sweep-gating multi switches, and the sweep generator starts its positive slope.

c. SWEEP ON LIGHT. The panel-mounted SWEEP ON light indicates that the sawtooth output from the sweep generator is running up (positive slope). The light is controlled by Q2 which in turn is driven by the sweep-gating multi.

The common load resistor for the SWEEP ON light and Q2 is R5 located on the low voltage power supply board.

When Q2 is conducting, its collector current through the common load resistor, R5, holds the voltage across the SWEEP ON neon bulb below its firing point. When Q2 is turned off, current through the common resistor, R5, turns on the SWEEP ON light. The base of Q2 is connected to the collector of Q10 (sweep-gating multi) by the divider R6-R7. When the sweep-gating multi is in the state which causes the sweep generator to produce a positive-going sawtooth (Q10 turned off), the collector of Q10 is at its most negative point, and the divider R6-R7 back biases Q2, and the SWEEP ON light is lit. When the sweep-gating multi is in the state to produce a negative going sawtooth, the collector of Q10 is near ground. The divider R6-R7 turns on Q2 and the SWEEP ON light is below its firing point (off).

d. BLANKING MULTI. The blanking multi, like the sweep-gating multi, is a typical saturating bi-stable multivibrator made up of Q13 and Q14. Its purpose is to provide a waveform to the leveling amplifier to turn off the power from the BWO during retrace (negative slope) of the sawtooth generator. Also, it provides an output to the pen-lift circuit for the use of pen recorders on the three slowest sweep ranges.

Unlike the sweep-gating multi, the blanking multi will not remain in either state indefinately. A bias current through CR26 and R19 to the +25 volt supply holds Q13 normally cut off and Q14 saturated. The blanking multi must be driven with an input to overcome this bias, and not just triggered.

A negative waveform from the collector of Q11 (sweep-gating multi) through the divider R50/R18 and CR25 holds the blanking multi turned on during the negative slope of the sawtooth. However, for proper blanking interval, the blanking multi must be turned on prior to the positive extreme of the sawtooth, and must

remain turned on after the negative extreme.

CR9 and Q4 turn on the blanking multi when the sawtooth has reached about +21 volts on the positive excursion, and the series pair, CR11 and CR12, holds the multi on until after the negative extreme of the sawtooth and until it has reached about -1 volt on its positive slope.

The divider made up of CR7, CR8, and R14 sets the voltage at the emitter of Q4 to about +21 volts. Because of the base current path through R17, Q4 is normally conducting. Collector current holds the cathode of CR27 to about +5 volts. When the sawtooth voltage has reached about +21 volts, CR9 conducts and turns off Q4. The resulting drop in collector voltage causes CR27 to conduct, turning on Q13 as long as the sawtooth is above +21 volts.

Before the sawtooth falls below +21 volts, the sweep-gating multi has switched, and the collector voltage of Q11 causes CR25 to conduct during the entire negative slope of the sawtooth.

When the sawtooth waveform goes negative with respect to ground, the series pair, CR11 and CR12, supplies current to R19, preventing the bias current from turning off Q13 until the sawtooth has increased to about -1 volt on its positive slope.

As a result of the above described action, the collector voltage of Q14 is clamped to ground while the sawtooth waveform traverses the voltage range of -1 to +21 volts on its positive slope. During the remainder of the sawtooth waveform, the collector voltage of Q14 is at -4 volts. The collector voltage of Q13 does just the opposite, it is at -4 volts during the sawtooth interval of -1 to +21 volts, and is clamped to ground during the retrace.

e. SWEEP LIMITING FOLLOWER. The sweep limiting follower is made up of Q5, Q6, and Q7. Its purpose is to clip the sawtooth waveform at 0 volts and +20 volts, and to provide the output sweep waveforms. The output drives (1) the START/CW dial, (2) the $\triangle$F, % of FULL BAND control, (3) the sweep output amplifier, and (4) the stop pulse output driver. Q5 is an emitter follower with its emitter limited to no more than one junction drop above the +20 volt supply by the diode, CR13. The emitter of Q5 provides an input to Q6, another emitter follower with its emitter limited to no less than 0 volts by the current steering network, CR14, CR15, and R21. Q7 is a current source to insure adequate base current for Q6 at the positive extreme of the sawtooth.

The emitter of Q5 follows one junction drop more positive than the sawtooth throughout the waveform except at the positive extreme where the emitter of Q5 is limited to no more than one drop above the +20 volt supply. While the sawtooth progresses through its most positive extreme, Q5 turns off, and the base of Q6 is held at +20.6 volts by the diode, CR13.

The emitter of Q6 follows one junction drop more negative than the emitter of Q5 throughout the waveform, except at the negative extreme where the current steering network, CR14, CR15, and R21, limit the emitter voltage of Q6 to no less than 0 volts.

The network made up of CR16 and CR17 in parallel with the emitter-base junction of Q6 and R20, essentially constitutes a floating power supply of nearly constant voltage to provide base current for Q6. Considering the junction drops involved and the value of R20, this provides a little less than 1 ma to be shared between base current for Q6 and emitter current for Q5. Current in excess of this amount provided by R24 and/or Q7, is shunted through CR16 and CR17.

When the sawtooth is at or below ground, Q6 is back biased and has no collector current. There is no base current for Q7, so it also is turned off. R24 to the +25 volt supply provides a little over 1 ma to the CR16/CR17 network. As the sawtooth waveform goes positive, the current available from R24 decreases because of the decreasing voltage across it. However, as the sawtooth goes positive, collector current through Q6 provides base current to Q7, and Q7 furnishes current to the network. In any case, throughout the range of operation, R20 has a constant voltage drop across it to provide base current for Q6 and emitter current for Q5.

The clipped sweep waveform (from 0 to +20 volts) is brought out from the emitter of Q6 to pin 7 for use by the STOP dial, and to drive the sweep inverter. A smaller amplitude sample of the sawtooth waveform is picked off the divider R60/R61 and brought out pin 8 to drive the $\triangle$F, % of FULL BAND control. The network made up of R60 to the sweep waveform, R61 to the -20 volt supply, and R202 ($\triangle$F, % of FULL BAND control) to ground; results in a sweep waveform across R202 starting at -1.1 volts at the beginning of the sweep, and progressing to +1.1 volts at the end of the sweep.

The stop pulse output driver, Q8, conducts at saturation, clamping its collector voltage to ground throughout the sweep waveform except during the positive extreme when Q5 is disconnected. Collector current from Q5 holds the junction of R27 and R62 at about -1 volt. The divider, R27/R25, forward biases the base of Q8, and Q8 holds its collector clamped at ground. During the positive extreme of the sawtooth waveform when Q5 is turned off, the divider, R62/R27/R25 turns off Q8. The collector of Q8 goes positive to a voltage determined by R28/CR18/R26 and the load connected to J304 (about +5.5 volts for loads above 10K). When the sawtooth starts its negative slope, Q5 again conducts, and the collector current from Q5 pulls up the bottom of R27. The divider R27/R24 provides base current for Q8, and the collector of Q8 is clamped to ground. The positive output at J304 is present during the interval that Q5 clips the top of the sawtooth waveform.

f. SWEEP INVERTER. The sweep inverter is an operational amplifier with a gain of one, centered around a dc level of +10 volts. The input to the sweep

inverter is from the sweep mode switch S202. In the "AUTO" and "TRIG" positions the input to the sweep inverter is the 0 to +20 volt sweep waveform from the sweep generator. In the "MANUAL" position, the input is a dc level from the manual sweep control. In the "CW" position input to the sweep inverter is grounded. The output of the sweep inverter, at pin 2 of the printed circuit board, drives the "start frequency dial". The output waveform is the mirror image of the input waveform centered around +10 volts. When the sweep inverter is being driven by the output waveform from the sweep generator, (auto and trig positions of the sweep mode switch) the output waveform from the inverter is a negative going sawtooth starting at +20 volts and ending at 0 volts. The sweep inverter is made up of Q15A, Q15B, Q16 and Q17.

Q15A and Q15B are connected as a voltage amplitude discriminator pair. The reference voltage for the discriminator pair is set to plus 10 volts at the base of Q15B, by the divider of R76, R77, and R78. The input resistor for the operational amplifier is R66. The feedback resistor is R64. The action of the operational amplifier is to produce whatever voltage is necessary at the top of R64 to cancel the input current from R66 and maintain the arm of R65 and the base of Q15A at +10 volts. Since R64 and R66 are equal, the output voltage from the operational amplifier will be the mirror image of the input voltage centered around the reference level of +10 volts. The common emitter resistor, R72, provides a constant current source of 2 ma to the amplitude discriminator pair, Q15A and Q15B. The quiescent condition of the discriminator pair is with each conducting 1 ma.

Since the emitter of Q16 is returned to the +20 volt supply, 1 ma of collector current through Q15A and the collector load resistor, R68, provides the base of Q16 with its conducting emitter-base junction drop. Collector current from Q16 provides base current for Q17 and in turn, collector current from Q17 establishes the output voltage level at the top of R64. Since there are three stages of gain between the base of Q15A and the collector of Q17, the output voltage at the top of R64 is an amplified version of, and out of phase with the error voltage at the base of Q15A.

g. MARKER GENERATOR. The marker generator is made up of five amplitude discriminator pairs and a common output stage. Each of the five amplitude discriminator pairs receives a dc level from its respective frequency dial. For those frequency dials which have not been selected as either a start or a stop dial, the input dc level will be between 0 and -20 volts, depending on the exact setting of the individual dial. The dials which are selected as a "start" or a "stop" dial provide a positive dc level to their respective discriminator pairs.

Each of the discriminator pairs receives a common input waveform from the output of the summing amplifier. This common input is a voltage between 0 and -20 volts, proportional to the output frequency of the BWO. When the output voltage from the summing amplifier is amplitude-coincident with any of the dc levels from the frequency dials, a marker is generated. A negative going pulse from the marker output amplifier is brought out pin 22 of the printed circuit board to S209 to reduce the power output from the BWO if markers have been selected by the front panel switch. A separate positive pulse is brought out pin 21 of the printed circuit board to the rear-mounted marker output jack, J306, whether markers have been selected or not.

Since all of the five amplitude discriminator pairs are identical, with the exception that each receives its dc reference level from a different frequency dial, only the amplitude discriminator for the number 1 frequency dial will be discussed.

Q1A and Q1B constitute the amplitude discriminator pair. Q2 is a constant current source of 2 ma from the -25 volt supply. Either Q1A or Q1B will conduct all of the available emitter current depending on which base is the most positive. When the BWO is being swept through its entire frequency range, the output voltage from the summing amplifier at the base of Q1B starts at 0 volts at the beginning of the sweep and progresses to -20 volts at the end of the sweep. Providing that the number one frequency dial has not been selected as a "start" or a "stop" dial, the dc level at the base of Q1A will be a voltage between 0 and -20 volts depending on the exact frequency selected by the number 1 frequency dial. At the beginning of the sweep, Q1B conducts all of the current supplied by Q2 and Q1A is turned off. At some point during the negative going sweep, the base of Q1B becomes more negative than the base of Q1A. At this point, Q1A conducts all the current supplied by Q2 and Q1B turns off.

Two back-to-back diodes, CR1 and CR2, are connected across the collectors of Q1A and Q1B. Both R1 and R4 are parallel collector loads for either Q1A or Q1B. CR1 conducts when Q1B is conducting and CR2 conducts when Q1A is conducting. The bases of Q3 and Q4 are always within one diode junction drop of each other. The base of Q3 is the most negative when Q1B is conducting and the base of Q4 is the most negative when Q1A is conducting.

Q3 and Q4 share the current from the common emitter resistor, R9 (about 10 ma). Either Q3 or Q4 conducts all of the current from R9, depending on which base is the most negative. The resistor network in the collector circuit of Q3 and Q4 made up of R11, R15, R12, R16, and R17, produce a negative going notch marker as conduction is transferred from Q3 to Q4 or vice-versa. Since the network is symmetrical the marker notch is the same, regardless of which way current is switched. The marker generated is the same, regardless of whether the BWO frequency crosses the reference point from low to high or high to low.

The clamping diodes CR5 and CR6 prevent the collector of the non-conducting transistor from falling below ground. The conducting transistor is saturated and its collector sits at about +2 volts. With either Q3 or Q4

conducting all of the current from R9, the cathode of CR7 is at very nearly ground potential. When the BWO frequency crosses the marker reference point and current switches from Q3 to Q4 (or vice-versa) a point in the transition is reached when Q3 and Q4 are conducting equally. With the current flow through Q3 and Q4 each equal to 5 ma, neither of the collector loads are held above ground. Both collectors fall down against the clamp diodes, CR5 and CR6. Then as current switching is completed and one transistor or the other conducts the full 10 ma, its collector is pulled back up to saturation. Thus, the cathode of CR7 normally sits at about ground potential, except when the current is switching between Q3 and Q4, at which time the cathode of CR7 drops to about -1 volt and then returns to ground, creating the negative going marker pulse.

The marker output amplifier is Q5. Its base voltage follows the most negative of the five marker discriminators through CR7, or its equivalent in the other four discriminators. Negative going markers are coupled from the emitter of Q5 through pin 22 of the printed circuit board to the rear panel marker output jack J306.

The two frequency dials which have been selected as the "start" and the "stop" dial provide a positive voltage to their respective discriminators. Since the output waveform from the summing-amplifier is between 0 and -20 volts, coincidence never occurs and no marker is generated.

h. STOP FOLLOWER. The stop follower is a bootstrapped emitter follower. Its input through pin 22 of the printed circuit board is from the arm of the frequency dial selected to determine the stop frequency. The input waveform is a positive-going sawtooth starting at 0 volts at the beginning of the sweep and progressing to some voltage between 0 and +20 volts at the end of the sweep, depending on the exact setting of the stop dial. The output voltage from the stop follower is identical to its input voltage except that the output is from a low impedance source. The output impedance of the stop follower is not effected by changes in the position of the stop dial as would be the case if the voltage were taken directly from the dial. The stop follower provides one of the inputs to the summing amplifier.

The stop follower consists of Q2A, Q2B, and Q1. The input voltage is applied to the base of Q2A. Collector current of Q2A provides base current to Q1. Collector current from Q1 in turn robs emitter current from Q2A through the emitter-base junction of Q2B. Until a state of equilibrium exists where the base of Q2B is at the same voltage as the base of Q2A.

The zener diode, CR3, and its bi-pass capacitor, C4 constitute a floating power supply for the common emitter resistor R4. R4 provides a constant 2 ma to be shared by the emitters of Q2A and Q2B. Collector current from Q1 supports the zener diode, as a result, collector current through Q2A is nearly constant throughout the entire voltage range of the stop follower. The base and collector of Q2B are tied together. The B half of the dual transistor, in this case, acts only as a temperature-compensating diode.

The start follower consisting of Q4A , Q4B , and Q3 functions in the same fashion as the stop follower, except that the output voltage from the start follower is the same as the voltage picked off of the start frequency dial. Both the stop and the start followers provide an input to the summing amplifier through R11 in the case of the stop follower and through R14 in the case of the start follower.

i. SUMMING AMPLIFIER. The summing amplifier is a multi-input operational amplifier made up of Q5A and B, Q6, Q7, and Q8. The input of the summing amplifier is the base of Q5A. Four separate input currents are provided to this point, each through its own respective 4.02K resistor. The inputs are (1) the output from the stop follower through R11 (2) the output from the start follower through R14 (3) the input from the external FM connector, J204, through R14 and (4) the input from ΔF, % of FULL BAND control, R202 through R21. The feedback resistor around the operational amplifier is R32. Within the gain limitations of the amplifier, the output voltage must be such that the current through R32 cancels the summation of all four input currents.

The base of Q5B is returned to ground which provides the reference point for the operational amplifier at 0 volts. Q5A and Q5B share the current from a common constant-current resistor, R23, from the -20 volt supply. Collector current from Q5A provides current to Q6. Collector current from Q5B provides base current to Q7. Q6 and Q7 make up a differential amplifier pair. Collector current from Q6 provides base current to Q8. Q8 in turn, drives the feedback resistor R32. Since there are three stages of voltage gain between the base of Q5A and the collector of Q8, the collector voltage of Q8 is an amplified version of and out-of-phase with the error voltage at the base of Q5A. Current through R32 cancels the input currents, and holds the base of Q5A at ground. The output voltage of the summing amplifier is limited to the voltage range of +1 volt to -23 volts by the zener diode CR7 and the back-to-back diode pair CR5, CR6. If the output voltage of the summing amplifier reaches either of these limits the output is fed back through the low impedance path of CR7 through CR5 or CR6 to the input to prevent any further departure. The back-to-back pair CR1 and CR2 prevents the input to the operational amplifier, at the base of Q5A, from going more than one junction drop above or below ground.

An output from the summing amplifier is provided through R37 and R38, through pin U of the printed circuit board, to the output frequency meter. R37 and R38 determine the scale-factor for the meter. An output is also provided through R35 and pin 17 of the printed circuit board to the rear panel mounted reference output jack, J307. The voltage at J307 is between 0 and -20 volts and is proportional to the output frequency of the BWO. The other outputs from the summing amplifier are through pin 14. They drive the voltage amplitude discriminators in the marker gen-

erator circuit, and the anode regulator. The summing amplifier also drives the sweep amplifier.

j. DIAL-SELECTOR SWITCHING MATRIX. The dial-selector switching matrix determines the function of the five panel mounted frequency dials. The five frequency dials are each ten-turn potentiometers. The numerals on the panel associated with each dial reads the low frequency limit from the BWO when the dial is at its counterclockwise extreme and the high frequency limit when the dial is at its clockwise extreme. The pick-off from each potentiometer is proportional between these limits. The dial-selector switching matrix determines the voltage or waveform across each particular potentiometer as well as determining the routing of the output picked off by the arm of the potentiometer.

The dial selected to determine the stop frequency has the 0 to +20 volt output from the sawtooth generator across the potentiometer and the output picked off from the arm is routed to the stop follower. The dial selected to determine the start frequency has the +20 to 0 volt output from the sweep inverter across the potentiometer and the output picked off by the arm is routed to the start follower.

If a particular dial is not selected for either "start" or "stop", the -20 volt supply is across the potentiometer and the output picked off the arm of the potentiometer is routed to the respective marker amplitude discriminator. If a particular dial is simultaneously selected as the start and the stop, the +20 volt supply is across the potentiometer and the output picked off by the arm is routed to the summing amplifier through the stop follower and the input to the start follower is grounded. Therefore, if a particular dial is selected as both start and stop, the output from the BWO will be a CW output at the frequency determined by the dial unless there is an additional input to the summing amplifier from the ΔF, % of FULL BAND control, or from the external FM input.

k. SWEEP AMPLIFIER AND HELIX DRIVER. The sweep amplifier, together with the helix driver constitute an operational amplifier which drives the helix and the collector of the BWO in accordance with the waveforms provided by the summing amplifier and the frequency pushing compensation from the leveler board. The feedback around the operational amplifier includes a non-linear network composed of resistors R39 through R67, diodes CR8 through CR16, and Q9A. The network is so arranged that each 10% segment of the frequency range of the BWO can be adjusted independently. When a linear sawtooth is applied to the sweep amplifier from 0 to -20 volts, a uniquely distorted sawtooth will be applied to the helix of the BWO to produce a linear sweep of frequency over the range of the BWO.

The input to the operational amplifier is the base of Q9B. The input signal is current flow through R57, R67, and Q9A (connected as a diode). The reference for the operational amplifier is established by the divider R72 and R77 to the -20 volt supply which sets the emitter voltage of Q9B to about -0.6 volts. The frequency pushing compensation from the leveling amplifier is applied through pin 16, R71 and R72 and modifies the reference voltage for the operational amplifier.

The output voltage of the operational amplifier is from pin N of the high voltage power supply board connected to the collector of the BWO. Feedback current is provided through the compensated divider R28 through R31, through pin 15 of the sweep amplifier board to the top of the non-linear network.

Output voltage from the operational amplifier is provided by the series regulator tubes V1, V2 and V3. Their cathode current is determined by the plate voltage of the driver, V4, which in turn is controlled by the transistor amplifier made up of Q9B, Q10, Q11, and Q12. The effect of the operational amplifier is to provide a waveform at the output, pin N, such that the current through the feedback network will cancel the input current and maintain the error voltage at the base of Q9 to a minimum.

Q12 is a constant-current source from the -25 volt supply which provides about 5 ma to the grid of V4. This bias current, if not offset by conduction of Q10 and Q11 pulls the grid of V4 negative, the plate of V4 goes positive and the cathode followers V1, V2, and V3, pull the collector and the helix of the BWO in a positive direction. The frequency goes up. Conversly conduction through Q10 and Q11 pulls the grid of V4 in a positive direction causing its plate voltage to go more negative. The cathode followers V1, V2 and V3 reduce the voltage on the collector of the helix of the BWO and the frequency comes down.

When the input sawtooth voltage at pin 14 is 0 volts (low frequency limit), current flow from the input through R47 through R39 and R73 to the +20 volt supply back biases all the diodes, and the only input to the operational amplifier is from the -20 volt supply through R70 and R68. The output voltage at pin L of the high voltage board is enough positive so the current through the compensated divider, R28 through R31, cancels the input current through R70 and R68. This permits R68 to adjust the low frequency limit.

As the input sawtooth goes from 0 to -2 volts, additional input current is provided through R57 and R67. The voltage at the output, pin L, must go positive enough to cancel this input current. The slope of the output waveform when the input is between 0 and -2 volts is a function of the ratio of the compensated divider, R28 through R31, and the series combination, R57 and R67. R67 is adjusted with the input sawtooth at -2 volts.

When the input sawtooth is more negative than -2 volts, the bottom of the divider (R47 through R39) is pulled down far enough for CR16 to conduct. When the input sawtooth is between -2 volts and -4 volts, current through R47, R56, and R66 provides input to the operational amplifier in addition to the above inputs. Within this range of input, current through R66 modifies the slope of the output waveform. R66 is adjusted

with the input at -4 volts.

At each additional -2 volts of the input waveform, another diode starts conducting, and the slope of the output waveform is further modified by current through the diode.

As a result of this non-linear feedback network, the total output waveform is made up of 10 individually adjustable slopes. Each of the adjustable slopes corresponds to a 2 volt segment of the input waveform, or 10% of the instruments frequency range. In making the frequency adjustments, it is important to start at "0" and make the adjustments sequentially through "10". Do not back up after an adjustment is made without starting over at the beginning. Each adjustment effects all higher adjustments.

Helix current from the BWO is through pin L of the printed circuit board, through the solenoid of K1, and through the zener diode CR4 to the cathodes of V1, V2 and V3. CR4 ensures a constant voltage difference between the helix and the collector of the BWO and K1 monitors the helix current. K1 is part of a self-latching relay system in conjunction with K102. If the helix current through the solenoid of K1 exceeds a specified value, K1 energizes and, together with K102, removes power from the BWO.

Several voltage taps are available from T102. The tap used depends on the helix voltage-range required by the specific BWO used. Also, the compensated voltage divider made up of R28 through R31 and C12 through C16 depends on the specific BWO used. Refer to the BWO installation instructions in the maintenance section of this manual for the specific values of R28 through R31, and the specific tap on T102.

1. BWO PROGRAMMED ANODE SUPPLY. The BWO programmed anode supply consists of Q1A, Q1B, Q2, and Q103. The purpose of the programmed supply is to increase the anode voltage on the BWO over the low-frequency half of the output frequency range to compensate for the inherent characteristics of the BWO. The output voltage from the programmed anode supply is a function of the frequency of the BWO, within limits set by adjustments in the anode supply itself.

The input to the programmed anode supply is through pin 20 of the printed circuit board. The input waveform is the output voltage from the summing amplifier. When the BWO is being swept over its entire frequency range, this input waveform is a 0 to -20 volt sawtooth. The programmed anode supply is a shunt regulator. The BWO anode and the programmed anode supply share a common load resistor, R110, to the +400 volt power supply.

The programmed supply consists of two operational amplifiers. Q1B and its associated components make up one of the operational amplifiers; Q1A, Q2 and Q3 make up the other operational amplifier. In the case of the first operational amplifier, the current steering diodes CR1 and CR2 select the input to Q1B. The input to Q1B is either the voltage waveform from the summing amplifier or the dc level selected by R12, depending upon which is the more positive. The input resistor to the operational amplifier is R8 and that portion of R7 below the pick-off arm. The feedback resistor around the operational amplifier is that portion of R7 above the pick-off arm. The input to the operational amplifier is referenced to ground since the emitter of Q1B is returned to ground.

When the input voltage from the summing amplifier is 0, the junction of R8 and R9 is held to one junction drop below ground by CR1. The top half of R7 provides base current for Q1B and the collector of Q1B is near ground. As the input waveform goes negative from ground, the junction of R8 and R9 goes negative reducing conduction of Q1B and the collector of Q1B moves in a positive direction. This action continues producing a positive going waveform at the collector of Q1B until the input voltage at pin 20 goes more negative than the voltage selected by the arm of R12. When the input voltage becomes more negative than the voltage picked off from R12, CR1 disconnects, and for the remainder of the sawtooth the input to the operational amplifier is the dc reference voltage picked off from R12.

As the summing amplifier output starts at 0 volts and goes negative to -20 volts, the collector of Q1B starts near 0 volts and proceeds in a positive direction with a slope determined by the adjustment of R7 to a dc level determined by R12. Once the collector of Q1B has reached this "max" level determined by R12, it stays at that dc level for the remainder of the input sweep. Refer to the maintenance section of this manual for the proper adjustment of R7 "slope" control and R12 "max" control.

The second operational amplifier in the programmed anode supply consisting of Q1A, Q2, and Q103 is driven by the collector of Q1B. The input resistor to the second operational amplifier is R29 and R59. The feedback resistor around the operational amplifier is R1. The input through R49 is a dc bias current determined by the adjustment of R4. The adjustment of R4 determines the starting voltage of the BWO anode while the output waveform from the summing amplifier is still at 0 volts. With the input from the summing amplifier at zero, the collector of Q1B is near zero and there is no input through R2. The output of the programmed anode supply at pin Z of the printed circuit board is whatever positive voltage is required for the current flow through R1 to cancel the current flow through R59, so that the base of Q1A is one junction drop above ground. When the collector of Q1B starts positive as a result of the input from the summing amplifier, current flow starts in R2. The voltage gain of Q1A, Q2 and Q103 pulls the output of the programmed anode supply at pin Z in a negative direction such that the sum total of the currents through R1 and R2 cancel the dc current through R59. As the collector of Q1B goes more and more positive the output from the programmed anode supply at pin Z becomes less and less positive.

The result of this overall action is that the BWO anode

voltage is the most positive when the output from the summing amplifier is zero and the BWO output frequency is at its low frequency limit. As the summing amplifier output goes negative, and the output frequency from the BWO increases, the anode voltage applied to the BWO is reduced. The output from the anode supply reaches its low limit at approximately the mid frequency range of the BWO, after which the voltage from the anode supply remains constant for the upper half of the BWO output frequency range.

m. MINUS 6.3 VOLT REGULATOR CIRCUIT AND FILAMENT OVER-VOLTAGE DETECTOR. Both the output frequency and the output power of the BWO are functions of the heater voltage. Therefore, it is necessary to regulate the BWO heater supply. The filament over-voltage detector removes power from the BWO if the heater exceeds -6.3 volts.

(1) BWO REGULATED HEATER SUPPLY. The -6.3 volt regulator circuit consists of CR8, Q6, Q7, Q105, Q104, and Q106. The -6.3 volt regulator circuit operates from the -16 volt power supply through a pair of normally-closed contacts of K102. The series dropping element in the regulated supply is the parallel combination Q104 and Q105. The voltage-amplitude comparitor-pair, Q6 and Q7, monitor the -6.3 volt supply and provide base current to Q106 in accordance with the supplies output voltage. The base of Q7 is held at -5.1 volts by the divider made up of R37 and the zener diode CR8. The base voltage of Q6 is proportional to the output voltage of the regulated power supply, determined by the divider R31, R33 and R34. When the output voltage of the regulated supply is less than -6.3 volts, Q7 conducts the current from the common emitter resistor R38, and Q6 has less than its normal collector current. Current through R35, to the -25 volt supply, provides base current for Q106. Q106, as an emitter follower, provides base current to both Q104 and Q105 to pull the output of the regulated supply down to -6.3 volts. When the output from the regulated supply reaches -6.3 volts, the divider R31, R33, and R34 provides base current for Q6. As a result of this base current, the collector current for Q6 reduces the current available to the base of Q106 and a condition of equilibrium is reached with the output from the regulated supply at -6.3 volts. Since there is one stage of gain between the error detection point, the base of Q106, and the output point, the emitters of Q104 and Q105, the power supply regulates at the voltage determined by the setting of R33 within the voltage gain limitations of Q6.

(2) FILAMENT OVER-VOLTAGE DETECTOR. The filament over-voltage detector consists of Q8, the zener diode CR11, and the fail-safe relay K102. The quiescent condition for the filament over-voltage detector is with Q8 turned off and K102 non-energized. In this condition, the normally closed contacts, K102C and K1A provide a ground at the cathode of CR103.

If the -6.3 volt supply exceeds -6.3 volts, current flow through the zener diode CR11 (a 6.2 volt zener) provides base current to Q8. Collector current from Q8 energizes K102. When K102 energizes the normally closed contacts K102C opens. Current flows from the -16 volt supply through R109, CR103 and the solenoid of K102 to ground, latching K102 in the closed position. When K102 closes, the normally closed contact K102B disconnects the -16 volt supply from the -6.3 volt regulator. K102A removes power from the high voltage transformer, T102.

n. LOW VOLTAGE REGULATOR. The low voltage regulator is made up of four regulated power supplies. The +25 volt supply, +20 volt supply, -20 volt supply and the -25 volt supply. Input power to the low voltage regulator is a +32 volts at pin 22 and a -32 volts at pin 1 from the low voltage power supply.

The -20 volt regulated supply consists of the zener diode CR24, Q10A, Q10B, Q7 and Q8. Q8 is the series regulating element. Q10A and Q10B make up a voltage-amplitude discriminator pair which shares a common 2 ma of emitter current, supplied by R29. The base of Q10B is held 9 volts more positive than the -20 volt output by the divider made up of CR24 and R32. The base of Q10A samples a specific portion of the -20 volt output, determined by the divider R25, R24, R21 and R23. Normal collector current for Q10A is about 1 ma. Collector current for Q10A is through R38 and R19 to the +20 volt supply. When Q10A is conducting about 1 ma, the voltage drop across R19 forward biases the base of Q7. Collector current for Q7 and base current for Q8 are through the common resistor R17 to the -25 volt supply. Collector current for Q7 subtracts from base current in Q8. The error voltage sampled at the base of Q10A is amplified by Q10A and Q7, and provides drive for the emitter follower Q8. Within the gain limitations of Q10A and Q7 the -20 volt regulator holds the voltage picked off the arm of R24 equal to the voltage drop across the zener diode CR24. The exact voltage to which the power supply regulates depends on the ratio determined by the divider R25, R24, and R23. For proper adjustment procedure for R24 consult the maintenance section of this manual.

The +20 volt regulator is made up of Q9A, Q9B, Q6 and Q5, with Q5 being the series regulating element, Q9A and Q9B make up a voltage-amplitude discriminator pair which share 2 ma of current from the common emitter resistor R36. The base of Q9B is returned to ground providing the reference point for the amplitude discriminator pair. The base of Q9A monitors half of the +20 volt supply through the divider R25, R34, and R33. Collector current for Q9A, provides base current to the emitter follower Q6 which in turn robs base current from the emitter follower Q5 through the common resistor R20. Within the voltage gain limitations of Q9A the +20 volt regulator maintains the voltage picked off of R34 equal to the base of Q9B or ground.

The +25 volt regulated supply is made up of Q3, Q4 and Q102. The emitter follower, Q102 is the series element and Q3 is the voltage comparator. The zener diode CR7 in series with the signal diode CR8 holds the emitter of Q3 at 5.1 volts plus one junction drop more negative than the +25 volt supply. The base of Q3 is returned to the +20 volt supply. Thus, Q3 can conduct only so long as the +25 volt supply is no more than 5.1

volts more positive than the +20 volt supply. When Q3 conducts, its collector current through R3 provides base current to the amplifier Q4. Q4 in turn provides base current to the emitter follower Q102 which pulls the +25 volt supply in a positive direction. When the +25 volt supply becomes 5.1 volts more positive than the +20 volt supply, current flow through CR8 and the zener diode CR7 pulls up the emitter of Q3 reducing collector current through Q3 and a state of equilibrium is achieved with the +25 volt bus held 5.1 volts more positive than the +20 volt bus.

The -25 volt regulated power supply consists of Q2, Q1 and Q101. The emitter follower Q101 is the series regulating element and Q2 is the voltage comparator. The -25 volt regulated supply functions the same as the +25 volt regulated supply discussed above, except that the current flow and voltage polarities are opposite. The -25 volt supply is held 5.1 volts more negative than the -20 volt regulated supply.

Because of the inter-relation of the power supplies, it is important that the -20 volt adjustment be made first and then the +20 volt adjustment. Refer to the maintenance section of this manual for the proper adjustment procedure of the regulated supplies.

o. LEVELER. The leveler consists of the square-wave generator, three operational amplifiers, a limit detector, and their associated inputs and feedback loops. The leveler determines the power output of the instrument by driving the control-grid of the BWO. Fig 3-2 is a simplified block diagram of the leveler in the unleveled mode of operation.

The various power determining inputs are summed at the input of the constant-gain operational amplifier. Each input has its individual voltage-to-current converting resistor. The input range of the constant-gain operational amplifier is 0 to +0.1 ma, resulting in an output of -5.6 volts (with 0 ma in) to 0 volts (with +0.1 ma in).

Either the POWER OUT control or the EXT AM input can independently drive the constant-gain operational amplifier through its full range. Since the inputs are summed, it is necessary to monitor the output and set limits to avoid the consequences of combinations that would over-drive the system. The limit detector provides low-impedance feedback around the constant-gain operational amplifier when its output reaches either limit (0 or -5.6 volts).

The gain of the programmed operational amplifier is an inverse linear function of the output frequency of the BWO. It has a gain of approximately 4 at the low frequency limit, and a gain of 1 at the high frequency limit.

The gain programming is accomplished by the gain-control amplifier as a result of the frequency-determining sawtooth at its input.

For the leveled mode of operation, refer to Fig 3-3. In the leveled mode of operation, the feedback loop around the constant-gain operational amplifier is opened, the input sensitivity is increased by a factor of 3, time constants are added to prevent oscillations, and an overall feedback loop is added from the RF

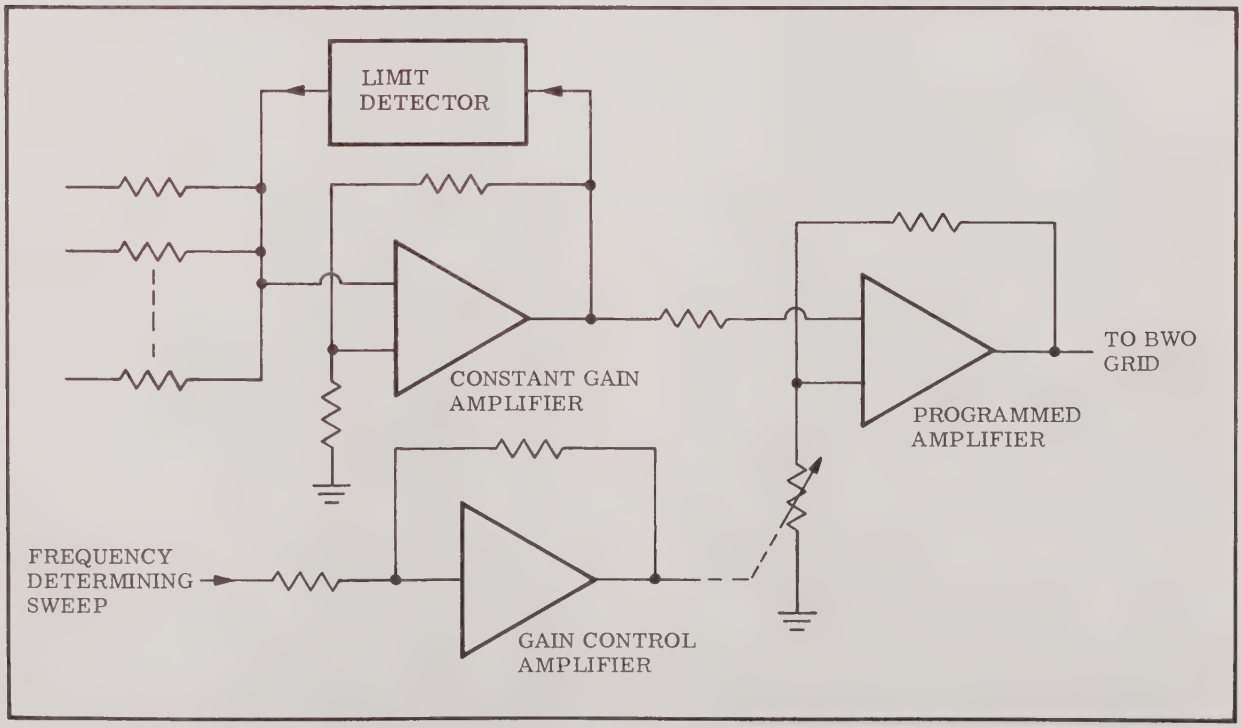


Fig 3-2 Simplified block diagram of the leveler amplifier in the unleveled mode.

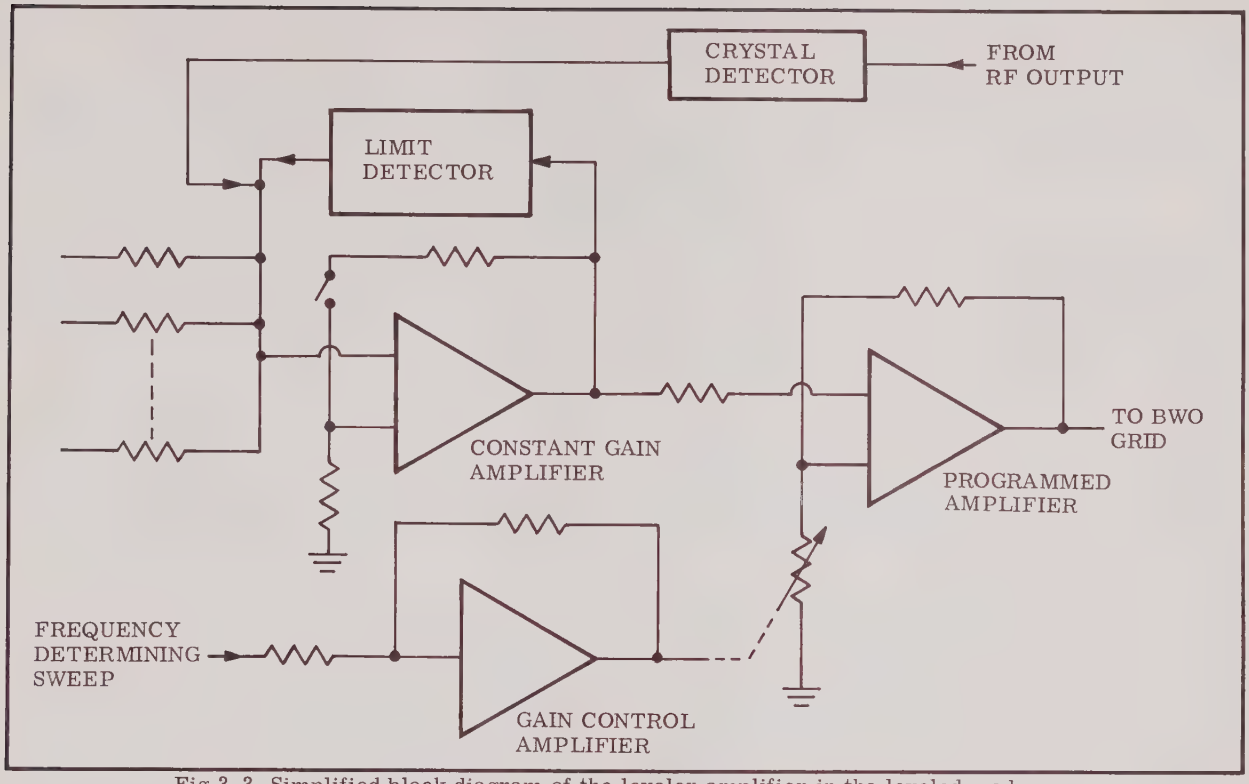


Fig 3-3 Simplified block diagram of the leveler amplifier in the leveled mode.

output back to the input of the constant-gain operational amplifier.

The operation of the leveler is essentially the same in the leveled mode as in the unleveled mode, except the system depends on the RF output from the BWO to cancel the power-determining inputs instead of the feedback around the constant-gain operational amplifier.

The constant-gain operational amplifier consists of Q3, Q2, Q4, and Q5. The input is at the base of Q3B. The input sensitivity is determined by R223 and R224 in parallel and the individual series resistors associated with each of the inputs. The operating voltage range at the base of Q3B is from 0 to +0.1 volts. A net input current from 0 to +0.1 ma (instantaneous summation of all inputs) will drive the operational amplifier through its full voltage input range.

The feedback network for the constant-gain operational amplifier is made up of R38, R40, and R227. R40 provides a constant +0.1 ma to R227. With 0 input to the operational amplifier, the output (at pin 14) must be at -5.6 volts, so the current through the feedback resistor, R38, can cancel the fixed +0.1 ma from R40 and hold the base of Q3A at a voltage equal to the base of Q3B (0 volts).

When the input of the operational amplifier is at +0.1 volt, the output at pin 14 must be at 0 so the +0.1 ma from R40 can hold the base of Q3A equal to the base of Q3B (+0.1 volts).

The "BAL" adjustment, R9 compensates for component tolerances throughout the amplifier, and permits adjusting the dc level of the relatively narrow input voltage window to be compatable with the fixed output limits. Because of the high gain within the amplifier, the various RC feedback time-constants are needed to prevent oscillations.

Limit Detector; Q6, Q7, and their associated components make up the limit detector. The purpose of the detector is to monitor the output of the constant-gain operational amplifier and provide a low impedance feedback around the operational amplifier when its output reaches either limit.

The quiescent condition of Q6 is determined by the divider R30/R33, the current gain of the transistor, and the collector current required by R23. Q6 has an equilibrium state with its collector at about -4 volts. At this level, R33 conducts enough current to supply the 2.5 ma for R30 plus enough base current for Q6 to support the 10 ma of collector current required by R23. The divider R22/R21/R16 holds the anode of CR6 just below ground, and the cathode of CR5 just above ground. The minimum junction drops required by CR5 and CR6 permits the input to the operational amplifier (the base of Q3B) to operate within its normal input voltage range, 0 to +0.1 volts.

If the output of the constant-gain operational amplifier

goes more positive than ground (input more positive than +0.1 volts), the diode CR8 conducts robing base current from Q6. With less base current, the collector of Q6 and the divider R22/R21 goes negative. Conduction through CR5 provides whatever negative input is required to prevent the output of the constant-gain operational amplifier from going any more positive.

If the output of the constant-gain operational amplifier goes more negative than about -5.6 volts, conduction through CR10 and CR9 provide additional base current to Q6 pulling its collector in a positive direction. As a result, CR6 provides whatever positive input is needed to prevent the output of the operational amplifier from going more negative.

As long as the output of the operational amplifier remains within the limits of 0 to -5.6 volts, the limit detector remains in its quiescent condition and neither CR5 nor CR6 conducts. Within the output limits stated above, the output of the operational amplifier is a function of its inputs.

MAX PWR Light. The MAX PWR light and its driver, Q7, provide a visible indication when the power-determining inputs are attempting to drive the BWO grid more positive than ground. The MAX PWR light and Q7 share a common load resistor (R4 on the low voltage rectifier board). When Q7 is conducting, the voltage at pin 22 is below the firing voltage of the neon bulb. Either Q7 or the neon conducts, but not both.

The quiescent condition for Q7 is conducting at saturation. The emitter is held at -5.1 volts by the divider R48/CR18. R46 provides enough base current to saturate Q7. When the output of the constant-gain operational amplifier goes more positive than ground, the collector of Q6 goes negative, CR17 conducts through R46 and turns off Q7. The voltage at pin 22 goes positive above the firing point of the noen bulb and the MAX PWR light turns on.

Programmed amplifier; The programmed amplifier consists of Q8, Q11, and Q12. The input voltage range at the base of Q8A is from 0 to -0.5 volts. The feedback loop is a divider from the output (collectors of Q11 and Q12) to the base of Q8B. The feedback divider is made up of R60 and the voltage-variable resistor, Q9. Q9 is a P channel FET operated in its drain saturation region. Its effective resistance is about 750 ohms at the low frequency limit, to about 3K at the high frequency limit.

The programmed amplifier will produce an output voltage between about -20 volts and ground, dependent on the feedback attenuator, R60/Q9, such that the voltage at the base of Q8B equals the input voltage at the base of Q8A.

Q12 is a constant-current source of 4 ma from the -25 volt supply to the output of the programmed amplifier. The voltage-amplitude discriminator pair, Q8A and Q8B, drive Q11 to provide more or less than the fixed 4 ma to pull the amplifiers output to the voltage needed to keep the base of Q8B equal to the voltage at the base of Q8A.

The output of the constant-gain operational amplifier is coupled to the input of the programmed amplifier through an attenuator and current steering network. The attenuator is made up of R39, R47, and R45 in parallel and the parallel combination in series with R37 to the output of the constant-gain operational amplifier. The attenuator matches the 0 to -5.6 volt output of the first amplifier to the 0 to -0.5 volt input of the programmed amplifier. The current steering diodes, CR11, CR15, and CR16 permit total cut-off of other power-determining inputs by the internal squarewave generator.

Gain control amplifier. The gain control amplifier consists of Q10 and Q9. Its purpose is to vary the gain of the programmed amplifier as an inverse function of the output frequency. The input at pin 20 is 0 volts when the BWO is at its low frequency limit, and -20 volts when the BWO is at its high frequency limit.

Q10 is an operational amplifier with three inputs; (1) a fixed minus current from the "LOW" adjustment, R65, (2) a minus current dependent on the frequency of the BWO from the "SLP" adjustment, R58, and (3) a fixed plus current from the +25 volt supply through R53. The gain of Q10 provides a voltage across R54 such that the current through R54 cancels the summation current of the three inputs.

The collector voltage of Q10 controls the effective resistance of Q9 and thus the gain of the programmed amplifier.

It is important to note that the gain control amplifier is not an input to the programmed amplifier, it simply determines the gain. Therefore, when the programmed amplifier output is near ground (maximum power output), the gain control circuit has little or no effect. The greatest effect of the gain control circuit is when the output of the programmed amplifier is near the cutoff limit of the BWO.

Internal Squarewave Generator. The internal squarewave generator is made up of Q1 and its associated circuitry. It provides a frequency-stable symmetrical squarewave, with the frequency being adjustable from 950 Hz to 1050 Hz. When the INT SQ WAVE pushbutton is depressed, -25 volts is applied to the squarewave generator. The circuit is a typical astable multivibrator. The output from the collector of Q1B is applied through pin 1, R217, and the diode CR204 to cancel other power-determining inputs. The collector of Q1B switches from about +25 mv to -1 volt. When the collector of Q1B is at -1 volt, CR11 conducts and disconnects CR15. The input to the programmed amplifier is then defined by the voltage drop across R45 caused by the current supplied through R47 from the -25 volt supply. The base of Q8A is held at -0.5 volts during the half cycle that Q1B conducts. This drives the grid of the BWO to its negative extreme and turns off output power, regardless of other power-determining inputs.

SECTION 4
MAINTENANCE

4-1 GENERAL

The E-H Model 570 Series Microwave Sweepers require a minimum amount of maintenance; however, normal aging of electronic components may eventually cause abnormal operation. Therefore, general maintenance and trouble shooting information is included in this section as a guide to restoring the instrument to normal operation.

4-2 ROUTINE MAINTENANCE

A regular program for maintenance and inspection every four to six months is recommended to effectively minimize equipment down time. As part of the regular maintenance and inspection procedure, the instrument should be carefully checked in the following manner:

a. Remove the Model 570 cover panels. Be careful of magnetic tools or your wrist watch around the BWO.

b. Make a thorough inspection of all wiring and cables. Check for frayed, loose or burned wires.

c. Check the physical integrity of all components. Look for evidence of burning or cracking, loose solder connections, leakage of insulation compounds, and general physical damage.

d. Check all swithces and controls for loose or broken terminals, tight or sticking shafts, etc.

e. If the internal panel surfaces and components have an excessive amount of dust or lint deposited on them, use a low pressure stream of air to remove the foreign material.

CAUTION

Do not clean the circuit boards or small internal components with a wiping cloth or solvents, since damage to the circuits may result.

f. Wipe the external surfaces of the instrument with a soft, damp cloth to remove dirt, fingerprints, and other foreign materials.

g. Remove and clean the metal air filter. The filter may be washed in soapy water. Rinse in clear water, dry and replace the filter on the instrument. The filter must be kept clean and unrestricted. Adequate cooling air flow is important to the life of the BWO.

h. Check the operation of the instrument in accordance with section 4-3, PERFORMANCE VERIFICATION.

i. Replace the cover panels if all checks indicate that the instrument is operating properly.

4-3 PERFORMANCE VERIFICATION

Before starting the performance verification, be sure all the test equipment is compatable with the frequency ranges to be tested. The RF plumbing is particularly important, including the directional couplers, wavemeter, powermeter, crystal detectors, and the interconnecting cables. If the RF hardware is not of the highest quality and compatable with the frequency range to be tested and the power levels to be encountered, the tests will be misleading and inconclusive.

a. EQUIPMENT NEEDED.

(1) Real-time oscilloscope, Tektronix 541 with 5 mv/cm vertical sensitivity, or equal.

(2) Power Meter, General Microwave Model 454A, or equal.

(3) Wavemeter, H-P 532, 536, or 537 Series, depending on the frequency range required, or equal.

(4) Crystal Detector (2 each), H-P 8470A, or equal.

(5) 20 dB Directional Coupler (10 dB for Models 576 and 577).

(6) 10 dB attenuator (compatable with the frequency range).

(7) BNC (2) and RG 9/U cables.

b. With the basic test set-up as shown in Fig 4-1, connect the vertical input of the test scope to the output of crystal detector #2, the horizontal input to the SWEEP OUT, J202.

(1) Set the controls on the 570 as follows:

SWEEP MODE	CW + ΔF
#1 FREQ DIAL	Low frequency limit
#2 FREQ DIAL	Low limit + 5%
#3 FREQ DIAL	Low limit + 10%
START/CW	Dial #2

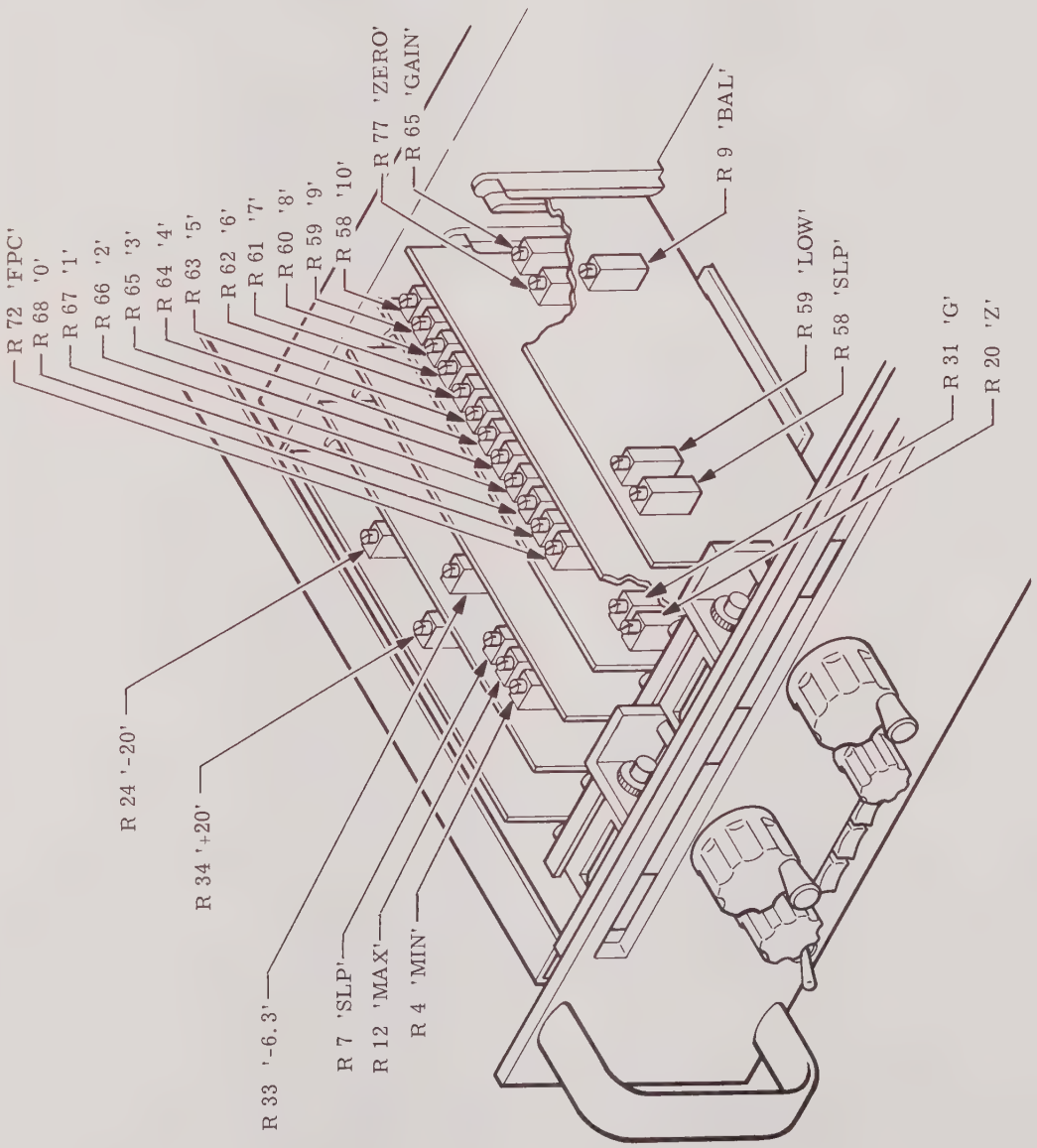


Fig 4-9 LOCATION OF CALIBRATION ADJUSTMENTS

(A)

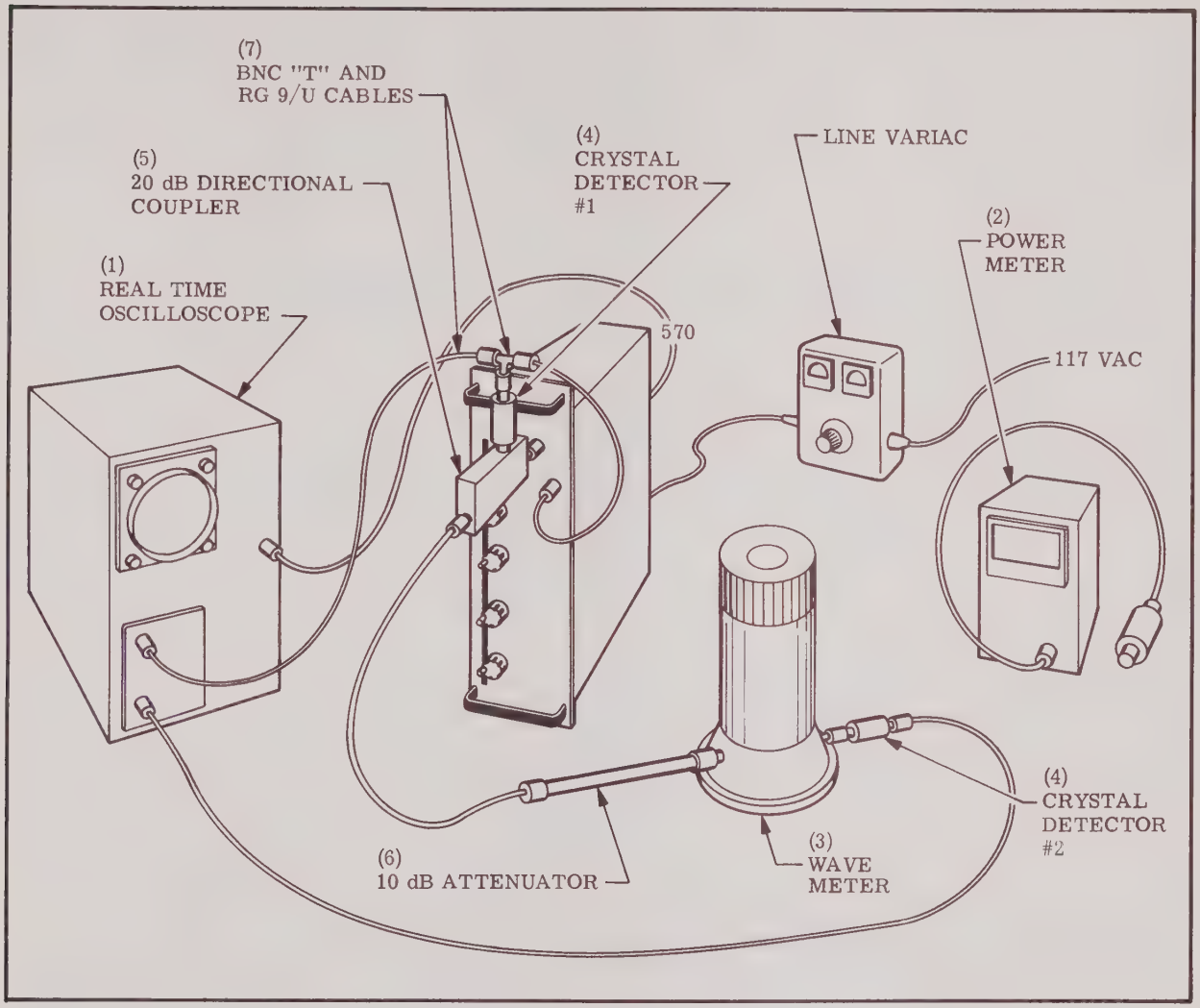


Fig 4-1 BASIC TEST SET UP

STOP	Dial #2
SWEEP TIME	1 ms
POWER OUT	mid range
Push buttons	only MARKERS depressed
ΔF, % of Full Band	ON

(2) Adjust the test scope horizontal sensitivity for 10 cm of horizontal deflection. Adjust ΔF so markers #1 and #3 are at the horizontal edges of the test scope graticule. The horizontal axis of the test scope is now calibrated for 1% of the frequency range per cm.

(3) When the wavemeter is set to the same reading as Dial #2, the wavemeter pip should be centered on the test scope ± 1 cm throughout the frequency range of the instrument. When any of the remaining dials are set to the same frequency as the wavemeter, the marker should agree with the wavemeter pip, ± 1 cm, throughout the frequency range of the instrument.

(4) Disconnect the wavemeter and connect the power meter to the 20 dB directional coupler. In the unleveled mode and the POWER OUT control clockwise, manually sweep the frequency range with the #2 FREQ DIAL and determine that the power output is not less than the rated output given in Fig 4-2 throughout the frequency range.

(5) Repeat step (4) in the leveled mode and determine that the power output does not vary more than 0.1 dB excluding coupler and detector variations.

(6) Check all controls for operation as labeled.

(7) Check output waveforms as labeled.

4-4 RECALIBRATION

If the Performance Verification indicates the instrument to be outside its specification limits, if the instrument has been repaired to correct a malfunction, or if a new BWO is being installed the instrument should be recalibrated according to the following procedure.

(1) Real-time oscilloscope, Tektronix 541 with

E-H MODEL	571	572	573	574
Freq Range, GHz	1.0-2.0	2.0-4.0	4.0-8.0	8.0-12.4
BWO Tube	SE 214A-3	SE 215A-17	SE 211A-5	WJ 2001-14
HV Rect Bd Transf Tap	Green	Blue	Blue	Green
HV Reg Bd 75KΩ R's	4	5	5	4
R Across K2	None	None	None	None
K2 Trp (±0.1mA)	8.7mA	8.0mA	7.5mA	7.6mA
1N3805 Zener	Yes	Yes	Yes	Yes
Sweep Ampl Bd R70	15KΩ	20KΩ	20KΩ	10KΩ
Leveler Networds X-tal Input R222	3KΩ	2KΩ	910Ω	1KΩ
C207	500 pF	500 pF	.001μF	.001 μF
Power Mtr C303	25 μF	25 μF	25 μF	25 μF
C304	0.1 μF	0.1 μF	0.1 μF	0.1 μF
R301	150Ω	200Ω	510Ω	330Ω
Max Helix I	4 mA	3.5 mA	3 mA	3 mA
BWO Camblock Cur Mtr R111	10.0Ω	12.7Ω	12.7Ω	16.9Ω
Max Cath I	17 mA	15 mA	12 mA	12 mA
Max Pwr Out	120 mW	90 mW	35 mW	50 mW
Residual FM (p-p)	20 kHz	40 kHz	80 kHz	88 kHz
V1, V2 & V3 plate volts	2350	2900	2900	2350

Fig 4-2

5 mv/cm vertical sensitivity, or equal.

(2) Power Meter, General Microwave Model 454A, or equal.

(3) Wavemeter, H-P 532, 536, or 537 Series, depending on the frequency range required, or equal.

(4) Crystal Detector (2 each), H-P 8470A, or equal.

(5) 20 dB Directional Coupler (10 dB for Models 576 and 577).

(6) 10 dB attenuator (compatable with the frequency range).

(7) BNC (2) and RG 9/U cables.

(8) Volt-Ohm-meter, 20,000 ohms/volt capable of resolving 1 μa.

(9) Line-voltage variac, 105 to 135 volts, at least 200 volt-amperes.

b. PRECAUTIONS

(1) The BWO contains a relatively strong focusing magnet. Use only non-magnetic mounting hardware and tools. Particularly do not allow magnetic material to be attracted to the BWO and bang against the case. The resulting shock can change the magnet strength and/or harm the tube. It is advisable to remove your wrist watch before handling the BWO. The magnetic field can ruin your watch, particularly if the watch is attracted to and sticks to the case.

(2) Be careful not to exceed the maximum beam current for the BWO. After the Model 570 is calibrated, the range of the controls will not exceed the rated beam current. However, during calibration it is possible to damage the tube. Pay particular attention when setting the power level, the anode voltage, and the grid voltage.

(3) When the covers of the Model 570 are removed, hazardous voltages are exposed. Depending on the particular model, voltages to 2500 volts may be present. In addition to the personal hazard, there are voltages present which exceed the input ratings of oscilloscope inputs, volt-ohm meter leads, etc. Be sure the test instrument can tolerate the voltages present on the point to be tested.

(4) Component density on the etched circuit boards is high. Leads are close together, and one side of the circuit board is a ground plane. Take care, when attaching volt-meter leads, oscilloscope probes, etc. that the probe touches only the point to be tested. Solid state junctions can easily be destroyed by allowing the test lead to touch two points or one point and ground.

(5) This calibration procedure is written based on installing a new BWO. If the instrument is to be recalibrated using the same BWO, then disconnect the BWO at the camblock before starting. Proceed the same as though a new BWO were being installed.

c. Refer to Fig 4-2 and make the following checks before starting the calibration procedure.

(1) Transformer tap.

(2) Number of 75 k resistors.

574-1	574-2	575	576	577
7.0-12.4	8.2-12.4	12.4-18.0	18.0-26.5	26.5-40.0
WJ 2001-13	VA-175M	VA-162M	VA-163M	VA-164M
Green	Green	Gray	Gray	Green
4	4	3	3	4
None	200Ω	300Ω	510Ω	510Ω
7.6mA	30mA	23mA	15mA	15mA
Yes	No; strap	No; strap	No; strap	No; strap
15KΩ	20KΩ	15KΩ	15KΩ	15KΩ
820Ω	100V Lev Ampl 2KΩ	100V Lev Ampl 1KΩ	100V Lev Ampl 5.1KΩ	100V Lev Ampl 2KΩ
.001 μF	500 pF	.001 μF	250 pF	500 pF
25 μF	25 μF	25 μF	25 μF	25 μF
0.1 μF	0.1 μF	0.1 μF	0.1 μF	0.1 μF
510Ω	200Ω	300Ω	100Ω	200Ω
3 mA	25 mA	18 mA	10 mA	10 mA
12.7Ω	10.0Ω	10.0Ω	16.9Ω	16.9Ω
12 mA	35 mA	25 mA	17 mA	17 mA
30 mA	24 mW	48 mW	24 mW	6 mW
108 kHz	80 kHz	112 kHz	170 kHz	270 kHz
2350	2350	1800	1800	2350

Fig 4-2 Continued

(3) Collector zener.
(4) Meter frequency range and current range.
(5) R70 on Sweep amplifier board for value.
(6) RC time constant of crystal input on leveler switch.
(7) RC time constant of power meter input on rear switch.
(8) Meter shunt in BWO cathode, R111.
(9) Frequency dials agree with BWO.
(10) Mechanical operation of frequency dial assemblies.
(11) Disconnect the BWO.

d. CHECK TIME DELAY

(1) Connect voltmeter from pin 1 of Fil and Anode BD (-) to ground (+). Turn POWER switch to STBY and time the interval until -6.3 volts appears at pin 1 of Fil and Anode Board. Should not be less than 40 sec.

e. SET REGULATED SUPPLIES

(1) Measure the voltage from pin 10 (-) of the etched circuit board sockets to ground (+). Adjust R24, "-20", for exactly -20 volts.

(2) Measure the voltage from pin 12 (+) of the etched circuit board sockets to ground (-). Adjust R34, "+20" for exactly +20 volts.

(3) With an oscilloscope, (5 mv/cm or better sensitivity) check the ripple on both the -20 volt supply and the +20 volt supply. Ripple should be less than 1 mv, and both supplies should regulate down to 105 volt line.

f. CHECK +25 and -25 VOLT SUPPLIES

(1) Connect voltmeter from -25 volt supply, pin 9 of the etched circuit board sockets (-), to the -20 volt supply, pin 10 (+). The -25 volt supply should be 5 volts more negative than the -20 volts supply ± 0.2 volts.

(2) Connect the voltmeter from +20 volt supply, pin 12 (-), and the +25 volt supply, pin 13 (+). The +25 volt supply should be 5 volts more positive than the +20 volt supply, ± 0.2 volts.

g. SET HEATER REGULATOR AND CHECK OVER-VOLTAGE CIRCUIT.

(1) Connect voltmeter from pin 17 (-) of the Fil and Anode BD to ground (+). Slowly increase the heater voltage by adjusting R33, "-6.3", until the fail-safe relay, K102, removes heater power. K102 should latch-up between 6.5 and 7.0 volts. If K102 fails to operate when the heater voltage is 7.0 volts, or the clockwise extreme of R33, "-6.3", whichever occurs first, check the voltage drop across CR11 (not more than 6.2 volts) and/or exchange R40 and R41.

(2) Turn off the power, Turn R33 counterclockwise several turns, and after 10 to 15 seconds turn the power back to STBY.

(3) Adjust R33, "-6.3", for -6.3 volts at pin 17 of the Fil and Anode Socket.

h. CHECK BEAM CURRENT SCALE

(1) Switch the panel-mounted meter selector switch to beam current.

(2) Turn the MANUAL SWEEP control full counterclockwise.

(3) With the POWER switch in STBY, connect a milliameter and a 1 k-ohm resistor in series between pin 5 of the Fil and Anode Bd (+) and pin 4 of the cam-block (-). Turn the MANUAL SWEEP control clockwise while watching both the panel-mounted beam current meter and the test milliameter

(4) If necessary, select a different value for R111 (between pins 18 and 21 of the leveler board socket). Smaller values of R111 cause the panel-mounted meter to read less. Final meter accuracy should be within 2%.

i. SET K1 TRIP CURRENT.

(1) Remove the Fil and Anode Board from the instrument. Be sure the POWER switch is OFF.

(2) Jumper one side of K1's solenoid to ground.

(3) Connect a millimeter and a 1 k-ohm resistor in series between the other side of K1's solenoid (-) and pin 5 of the Fil and Anode socket (+).

(4) Turn the POWER switch to STBY. Turn the MANUAL SWEEP control clockwise while observing the test millimeter. Adjust K1 to trip at the current value given in Fig 4-1 as max helix current for the particular BWO. When K1 trips, it should latch-up the fail-safe relay. K102, and turn off the STBY light.

(5) Remove the jumper and the milliameter from K1, and replace the Fil and Anode Board.

j. TIMING CHECKS

(1) Display the BLANKING OUTPUT from J305 on the test oscilloscope. SWEEP MODE in AUTO.

(2) Determine that the vernier SWEEP TIME control covers at least the limits selected by the decade SWEEP TIME switch.

(3) In the AUTO sweep mode, check the following output waveforms:

Stop Pulse (J304)	+5 volts
Blanking Output (J305)	-4 volts
Markers (J306)	+1 volt
Reference Output (J307)	0 to -20 volts when the full band is being swept.

(4) With an ohm-meter connected to the PEN LIFT connectors (J302), check for contact closure during forward sweep time on the three slowest positions of the SWEEP TIME switch.

k. ADJUST SUMMING AMPLIFIER.

(1) SWEEP MODE to MANUAL.

(2) ΔF to ON

(3) SWEEP TIME to 1 msec.

(4) Connect test scope:

(4a) Horizontal input to SWEEP OUTPUT.

(4b) Vertical input to MARKER OUTPUT.

(4c) Adjust horizontal sensitivity of test scope for 10 cm deflection centered on the graticule.

(5) Set all frequency dials to the low limit.

(6) Adjust ΔF control so all four markers are displayed on the test scope.

(7) Select the same frequency dial as both START/CW and STOP. Sequentially select each frequency dial as both START/CW and STOP. Select the dial that results in the "worst case" marker spread.

(8) Turn the selected frequency dial clockwise until the right hand marker is centered on the graticule. Then advance the selected frequency dial exactly 1% of the instruments frequency range further clockwise.

(9) Adjust ΔF so the center of the right hand frequency marker is at the left hand edge of the graticule. Return the selected frequency dial to the low limit. The graticule of the test scope is now calibrated at 0.2% of the frequency range per centimeter.

(10) Adjust R20, "Z", to center the two outboard markers on the graticule. All four markers should be in the two center centimeters (± 0.2% of the frequency range). Refer to Fig 4-3.

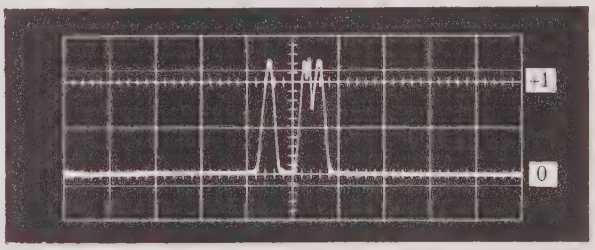


Fig 4-3 Marker Output with all 5 frequency dials at the same frequency. Horizontal deflection is 0.2% of the frequency range per cm.

(11) Set all frequency dials to the high frequency limit. Adjust R31, "G", to center the two outboard markers on the graticule.

(12) Repeat the low and high frequency limit adjustments until there is no further interaction.

l. ADJUST SWEEP INVERTER.

(1) Set controls:

(1a) All frequency dials to the high limit.

(1b) Select dial #1 as START/CW, dial #2 as STOP.

(1c) SWEEP MODE to MANUAL.

(2) With the MANUAL SWEEP control centered, adjust R77, "ZERO", to center the group of markers on the graticule. Refer to Fig 4-3.

(3) While rotating the MANUAL SWEEP control between its limits, adjust R65, "GAIN", so the markers do not move on the display.

(4) Repeat Steps 2 and 3 until the marker group remains totally contained within the 2 center centimeters of the graticule throughout the full rotation of the MANUAL SWEEP control.

m. CHECK OUTPUT-FREQ-METER ACCURACY.

(1) Switch the panel-mounted meter-selector-switch to GHz. With the instrument at the high frequency limit, the meter should read full-scale ± 4%.

n. PRESET LEVELER AMPLIFIER

(1) Set controls to:

(1a) SWEEP MODE to CW.

(1b) ΔF to OFF.

(1c) Set dial #1 to the low frequency limit

and select as START/CW.

(1d) Set dial #5 to the high frequency limit and select as STOP.

(1e) LEVELED pushbutton in the unleveled position.

(2) Connect multi-meter between test point #1 and test point #2 on the leveler board. Adjust R9, "BAL", for 0 current between the two test points ± 1 μa. Check full range of POWER OUT control. Remove milliameter

(3) Set controls to:

(3a) SWEEP MODE to AUTO.

(3b) Frequency dial #1 to low limit and select as START/CW.

(3c) Frequency dial #2 to high limit and select as STOP.

(3d) POWER OUT full clockwise.

(3e) BLANKED RETRACE depressed.

(3f) ΔF to OFF.

(3g) LEVELED pushbutton in the unleveled position.

(4) Display the voltage waveform at pin 17 of the leveler board on the test scope (5 volts/cm). Adjust R65, "LOW" for -20 volts at the low frequency limit. Adjust R58 "SLP" for -5 volts at the high frequency limit. Refer to Fig 4-4.

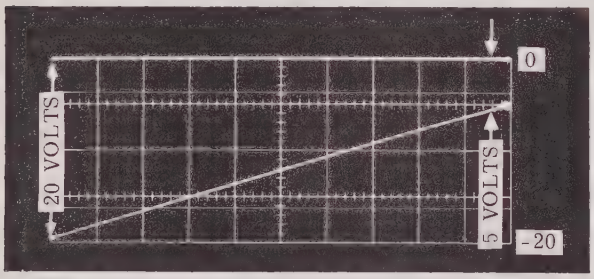


Fig 4-4 Output from leveler board. Upper trace is forward sweep at full power setting. Lower trace is retrace.

(5) Depress MARKERS, set POWER OUT at center, check for markers on the more positive of the two traces, Markers should not be present when the POWER OUT control is full clockwise.

(6) Depress INT SQ WAVE pushbutton. Rotate SWEEP TIME variable control counterclockwise to stop the square wave on the display. The squarewave should switch between the two traces at any setting of the POWER OUT control.

(7) Turn POWER OUT control full clockwise. Switch the test scope to its triggered time base. Adjust the test scope triggering for "internal" and sync the display.

(8) Determine that the SQ WAVE FREQ control covers the range of 950 to 1050 Hz.

d. CHECK HIGH VOLTAGE SUPPLIES.

(1) Switch POWER to ON.

(2) Check high voltage at the anode caps of the three 8068's on the high voltage regulator board as shown in Fig 4-2; V1, V2, and V3 plate volts.

(3) Check +82 volts at pin C of the High Voltage Regulator Board.

(4) Check 134 volts between pin A (-) of the High Voltage Regulator Board and the junction of R3 and R6 (+).

p. PRESET THE HELIX VOLTAGE.

(1) In the CW mode at the low frequency limit, measure the voltage at Pin L of the High Voltage Regulator Board. Adjust R68, "O" on the Sweep Amplifier Board, for the low-frequency helix voltage on the particular BWO specification sheet.

(2) Check the collector voltage at pin N of the High Voltage Regulator Board. It should be approximately 50 volts more positive than the helix.

q. PRESET THE PROGRAMMED ANODE SUPPLY.

(1) In the CW mode at the low frequency limit, measure the voltage at pin 22 of the Fil and Anode Board. Adjust R4, "MIN" on the Fil and Anode Board for the anode voltage on the particular BWO specification sheet.

(2) Display the voltage waveform at pin 22 of the Fil and Anode Board on the test oscilloscope. In the AUTO mode, sweep the frequency range from the low to the high limit. Adjust R7, "SLP" on the Fil and Anode Board, so the break point occurs at the mid-frequency range. Adjust R12, "MAX" on the Fil and Anode Board, so the anode voltage at the high frequency limit is 90% of the anode voltage at the low frequency limit. Refer to Fig 4-5.

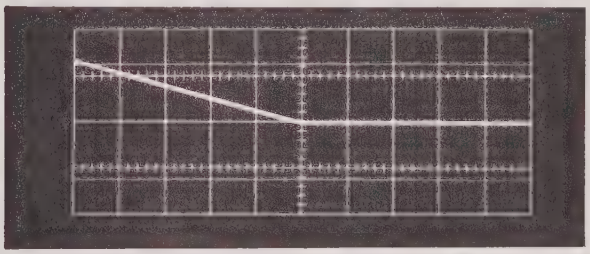


Fig 4-5 Preset programmed anode supply. Horizontal deflection is the full frequency range.

r. INSTALL THE BWO AND THE ELAPSED-TIME METER.

s. FREQUENCY ADJUSTMENT.

(1) Connect the RF output through 10 dB of attenuation, the wavemeter, and the crystal detector to the vertical input of the test scope. Connect the horizontal input of the test scope to the SWEEP OUT, J202.

(2) Set the controls to:

(2a) SWEEP MODE to CW +ΔF.

(2b) START/CW Dial at the low frequency limit.

(2c) POWER OUT full clockwise.

(2d) Panel-mounted meter selector switch to BEAM CURRENT.

(3) Manually sweep the START/CW dial through the full frequency range and determine that BEAM CURRENT does not exceed the max rated value as stated in Fig 4-2.

(4) Calibrate the test scope display for 0.2% of the frequency range per cm.

(4a) In the CW mode with the ΔF on, set

Model	571	572	573	574 574-2	574-1	575	576	577
Band (GHz)	1-2	2-4	4-8	8-12.4	7-12.4	12.4-18	18-26.5	26.5-40
Cal Pot.								
0	1.000	2.000	4.000	08.00	06.900	12.400	18.00	26.50
1	1.100	2.200	4.400	08.45	07.4625	12.9625	18.875	27.875
2	1.200	2.400	4.800	08.90	08.025	13.525	19.75	29.25
3	1.300	2.600	5.200	09.35	08.5875	14.0875	20.625	30.625
4	1.400	2.800	5.600	09.80	09.150	14.650	21.50	32.00
5	1.500	3.000	6.000	10.25	09.7125	15.2125	22.375	33.375
6	1.600	3.200	6.400	10.70	10.275	15.775	23.25	34.75
7	1.700	3.400	6.800	11.15	10.8375	16.3375	24.125	36.125
8	1.800	3.600	7.200	11.60	11.400	16.900	25.00	37.50
9	1.900	3.800	7.600	12.05	11.9625	17.4625	25.875	38.875
10	2.000	4.000	8.000	12.40	12.40	18.00	26.50	40.00

Fig 4-6

the START/CW and one marker to the same frequency. With the marker dial, set the marker to the center of the graticule. Move the marker dial exactly 1% of the frequency range, and adjust △F so the marker is at the graticule edge.

(5) Set the wavemeter and the START/CW dial to the low frequency limit and adjust R68, "O", to center the wavemeter pip on the test scope.

(6) Make the remaining frequency adjustments at the frequencies shown in Fig 4-6. Proceed sequentially from "O" through "10". Once an adjustment has been made, do not come back to it.

(7) Check △F range. Turn the △F control full clockwise. Set a marker at each end of the graticule. The difference between the two marker frequencies should be at least 10% of the instruments frequency range.

t. FREQUENCY PUSHING COMPENSATION.

(1) Using the same set-up as in paragraph s, set the wavemeter and the START/CW dial to the same frequency and adjust R72, "FPC" on the Sweep Amplifier Board, for minimum frequency shift as the POWER OUT control is rotated through its full range. Maximum frequency excursion should be less than 0.4% of the frequency range throughout the range of the POWER OUT control. Check frequency pushing at the low limit, high limit, and center of the frequency range.

u. ADJUST PROGRAMMED ANODE SUPPLY FOR UNLEVELED OUTPUT.

(1) Connect the RF output through 20 dB of attenuation, and the crystal detector to the xtal leveling input and the vertical input of the test scope. Connect the horizontal input of the test scope to SWEEP OUT, J202.

(2) With the instrument sweeping the full frequency range in the AUTO mode and the POWER OUT control full clockwise, adjust R12, "MAX", and R7, "SLP", for the most level power output over the entire frequency range. Keep the anode voltage as low as possible to get rated power over the entire frequency range. Refer to Fig 4-7.

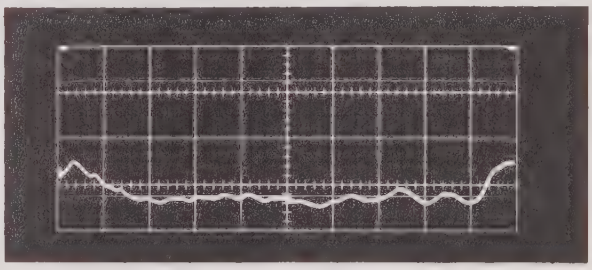


Fig 4-7 Voltage from crystal detector in the unleveled mode. Horizontal deflection is the full frequency range of the Model 570.

v. ADJUST LEVELER AMPLIFIER GAIN. (Do not attempt to adjust the leveler with a board extender).

(1) Display the waveform at pin 17 of the leveler board with the LEVELED and the BLANKED RETRACE pushbuttons depressed.

(2) With the POWER OUT control set for the minimum power output that will clearly separate the sweep and retrace on the test scope, adjust R65, "LOW" on the leveler board, for 3 volts difference between the trace and the retrace at the low frequency limit. Adjust R56, "SLP" on the leveler board, for 1 volt difference between the trace and the retrace at their closest point.

(3) Check for no oscillations at any power setting and the retrace line stays at zero power during the entire retrace. Refer to Fig 4-8.

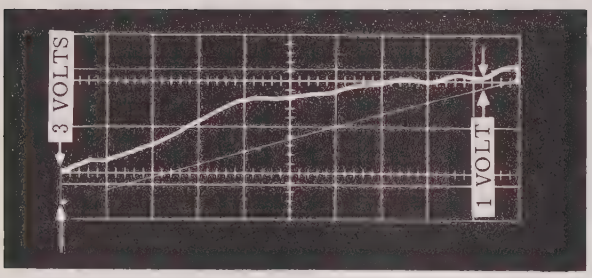


Fig 4-8 BWO grid waveform in the leveled mode. Horizontal deflection is full frequency range.

(4) Set SWEEP TIME to 100 ms. Adjust POWER OUT and check that MAX PWR light flashes when the output exceeds the leveling limit.

w. CHECK POWER OUTPUT.

(1) In the CW mode, unleveled, the power output should not be less than the value given in Fig 4-2 at any frequency. Check that beam current does not exceed the maximum value given in Fig 4-2.

x. CHECK RESIDUAL FM.

(1) Connect the RF OUTPUT through a 10 dB attenuator, wavemeter, and crystal detector to the input of the test oscilloscope. Drive the external horizontal input of the test scope with the SWEEP OUT. Adjust the horizontal sensitivity of the test scope for 10 cm of horizontal deflection.

(2) In the AUTO mode, set the START/CW dial so the center of the wavemeter pip is at the left edge of the graticule. Increase the wavemeter setting 0.05% of the frequency range of the Model 570, and set the STOP dial so the center of the wavemeter pip is at the right edge of the graticule. The test scope graticule is now calibrated so each minor horizontal scale mark (2 mm) is 10 parts per million of the frequency range of the Model 570.

(3) Increase the vertical sensitivity of the test scope to 5 mv/cm. Residual FM is displayed as the horizontal width of the trace which defines the edge of the wavemeter pip.

(4) Residual FM should be no more than 10 ppm.

y. Repeat paragraph s, Frequency Adjustments.

z. Check AM Modulation Sensitivity and Bandpass.

(1) Connect the RF OUTPUT through 10 dB of attenuation and the crystal detector to both the crystal leveling input and to the test scope vertical input. Trigger the test scope internally.

(1a) SWEEP MODE to CW.

(1b) Position one of the five frequency dials to the low end of the frequency range and select it as START/CW.

(1c) ΔF to OFF.

(1d) Unleveled, and no other modulation except EXT AM.

(2) Apply a 20 volt p-p sinewave (up to 100 kHz) to the EXT AM connector and determine that the EXT AM input signal produces full power on the positive peaks with the POWER OUT control set full counterclockwise. Also determine that the EXT AM input signal reduces the power output to 0 on the negative peaks when the POWER OUT control is full clockwise.

(3) With the same set-up as in step (1), and the POWER OUT control counterclockwise, apply a sinewave input to the EXT AM connector. The external AM signal should be any frequency up to 100 kHz and an amplitude that will produce a convenient deflection on the test oscilloscope. Be sure that the input amplitude does not cause clipping of the output on the positive peaks. Measure the input signal amplitude and observe the exact deflection produced on the test scope.

(4) Increase the frequency of the input signal to 1 mHz and the same amplitude as in step (3), and determine that the deflection on the test scope is not less than 70% of the deflection noted in step (3).

(5) Repeat steps (3) and (4) at the high frequency limit.

(6) In the leveled mode, repeat steps (3), (4), and (5) except use 5 kHz as the reference frequency in step (3) and 50 kHz as the test frequency in step (4).

SECTION 5
PARTS LIST

5-1 ORDERING INFORMATION

Replacement parts may be ordered through your E-H Representative or from the factory. To be certain that you receive the proper replacement parts, always include the following information with your order:

a. Model number and serial number of the instrument on which the replacement parts will be installed.

b. Circuit or drawing reference for which each part is intended.

c. E-H part number. For factory repair of this instrument, or warranty claim, contact E-H Research Laboratories, Inc., Customer Service Department, and provide:
(1) Instrument Model number and serial number.
(2) Full details concerning the nature of the malfunction.

Parts in this instrument may be replaced with parts of like value and quality providing the replacement part is the same physical size and has the value and tolerances specified in the parts list. The parts marked with an asterisk (*), "factory select", are the same for all instruments of the same frequency range. They adapt the circuitry to fit the BWO of that particular frequency range. They are not "in house" selected for any characteristic beyond their normal manufacturers specifications.

The circuit or drawing reference numbers start with "1" on each etched circuit board. For example; there is an R1 on the Sweep Generator Board (A105), there is also an R1 on the Marker Board (A103). It is necessary to include the etched circuit board terminology in the circuit number to distinguish between the two.

Normally individual wafers or contacts are not supplied for switch repair. If switch repair is necessary it is more practical to replace the entire switch.

Etched circuit boards are available complete with mounted components. Refer to the following index for E-H part numbers. The individual components on each board are tabulated in the paragraph noted for that board.

INDEX

		E-H Part #s	Paragraph
A101	Low Voltage Regulator	D 12294	5-2
A102	Filament and Anode	D 12295	5-3
A103	Markers	D 12296	5-4
A104	Sweep Amplifier	D 12297	5-5
A105	Sweep Generator	D 12298	5-6
11550	High Voltage Regulator	D 12300	5-7
11546	High Voltage Rectifier	D 12302	5-8
11552	Low Voltage Rectifier	D 12301	5-9
A106	Leveler	D 12349	5-10

5-2 LOW VOLTAGE REGULATOR BOARD

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
C1	Cap., 15μf, 50v	316-062
C2	Cap., Disc., 0.1μf	311-014
C3	Cap., Disc., .002μf	311-017
C4	Cap., Disc., .01μf	311-012
C5	Cap., Disc., .01μf	311-012
C6	Cap., 15μf, 50v	316-062
C7	Cap., Disc., .002μf	311-017
C8	Cap., Disc., 0.1μf	311-014
C9	Cap., Disc., .002μf	311-017
C10	Cap., 25μf, 25v	316-028
C11	Cap., Disc., .002μf	311-017
C12	Cap., Disc., .002μf	311-017
C13	Cap., Disc., .002μf	311-017
C14	Cap., 25μf, 25v	316-028
C15	Cap., 20μf, 15v	316-064
C16	Cap., Disc., .002μf	311-017
C17	Cap., Disc., .002μf	311-017
C18	Cap., Disc., .002μf	311-017
C19	Cap., 20μf, 15v	316-064
C20	Cap., 25μf, 25v	316-028
C21	Cap., 25μf, 25v	316-028
C22	Cap., Disc., .002μf	311-017
C23	Cap., 25μf, 25v	316-028
C24	Cap., 15μf, 50v	316-062
C25	Cap., 15μf, 50v	316-062
CR1	Diode, 1N914	376-061
CR2	Diode, 1N914	376-061
CR3	Diode, 1N914	376-061
CR4	Diode, 1N914	376-061
CR5	Diode, 1N914	376-061
CR6	Diode, 1N914	376-061
CR7	Diode, 1N751A	374-022
CR8	Diode, 1N914	376-061
CR9	Diode, 1N914	376-061
CR10	Diode, 1N914	376-061
CR11	Diode, 1N751A	374-022
CR12	Diode, 1N914	376-061
CR13	Diode, 1N914	376-061
CR14	Diode, 1N914	376-061
CR15	Diode, 1N4005	376-034
CR16	Diode, 1N914	376-061
CR17	Diode, 1N914	376-061
CR18	Diode, 1N914	376-061
CR19	Diode, 1N914	376-061
CR20	Diode, 1N914	376-061
CR21	Diode, 1N914	376-061
CR22	Diode, 1N914	376-061
CR23	Diode, 1N914	376-061
CR24	Diode, 1N938	374-061
CR25	Diode, 1N914	376-061

5-2 LOW VOLTAGE REGULATOR BOARD Continued

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
CR26	Diode, 1N914	376-061
Q1	Transistor, 2N3053	663-062
Q2	Transistor, P35201	A 11747
Q3	Transistor, 2N3053	663-062
Q4	Transistor, P35201	A 11747
Q5	Transistor, 2N3053	663-062
Q6	Transistor, P35201	A 11747
Q7	Transistor, P35201	A 11747
Q8	Transistor, P35201	A 11747
Q9	Transistor, DN2521	A 11748
Q10	Transistor, DN2521	A 11748
R1	Resistor, 100Ω, 1/4W, 5%	595-101
R2	Resistor, 0.39Ω, 1W, 5%, WW	610-088
R3	Resistor, 1K, 1/4W, 5%	595-102
R4	Resistor, 680Ω, 1/4W, 5%	595-681
R5	Resistor, 2K, 1/4W, 5%	595-202
R6	Resistor, 1.2Ω, 2W, 5%, WW	610-089
R7	Resistor, 47Ω, 1/4W, 5%	595-470
R8	Resistor, 15K, 1/4W, 5%	595-153
R9	Resistor, 2K, 1/4W, 5%	595-202
R10	Resistor, 15K, 1/4W, 5%	595-153
R11	Resistor, 47Ω, 1/4W, 5%	595-470
R12	Resistor, 1K, 1/4W, 5%	595-102
R13	Resistor, 0.39Ω, 1W, 5%, WW	610-088
R14	Resistor, 75Ω, 1/4W, 5%	595-750
R15	Resistor, 680Ω, 1/4W, 5%	595-681
R16	Resistor, 1.2Ω, 2W, 5%, WW	610-089
R17	Resistor, 820Ω, 1/2W, 5%	595-821
R18	Resistor, 2K, 1/4W, 5%	595-202
R19	Resistor, MF, 22.6K, 1/2W, 1%	618-062
R20	Resistor, 680Ω, 1/4W, 5%	595-681
R21	Resistor, MF, 21.5K, 1/2W, 1%	618-061
R22	Resistor, 2K, 1/4W, 5%	595-202
R23	Resistor, MF, 4.02K, 1/2W, 1% 20PPM/°C	618-047
R24	Potentiometer 500Ω	551-035
R25	Resistor, MF, 4.02K, 1/2W, 1% 20PPM/°C	618-047
R26	Resistor, 47Ω, 1/2W, 5%	596-470
R27	Resistor, 47Ω, 1/2W, 5%	596-470
R28	Resistor, 5.1K, 1/4W, 5%	595-512
R29	Resistor, MF, 4.22K, 1/2W, 1%	618-048
R30	Resistor, MF, 681Ω, 1/2W, 1%	618-042
R31	Resistor, 10K, 1/4W, 5%	595-103
R32	Resistor, MF, 1.47K, 1/2W, 1%	618-043
R33	Resistor, MF, 4.02K, 1/4W, 1% 20PPM/°C	618-047
R34	Potentiometer 100Ω	551-036

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
	5-2 LOW VOLTAGE REGULATOR BOARD Continued	
R35	Resistor, MF, 4.02K, 1/2W, 1% 20PPM/°C	618-047
R36	Resistor, JF, 10K, 1/2W, 1%	618-055
R37	Resistor, 10K, 1/4W, 5%	595-103
R38	Resistor, 5.1K, 1/4W, 5%	595-512
	5-3 FILAMENT & ANODE SUPPLY	
C1	Cap., Disc., .002μf	311-017
C2	Cap., Disc., .01μf	311-012
C3	Cap., .002μf	311-017
C4	Cap., Disc., 50pf	311-006
C5	Cap., Disc., .002μf	311-017
C6	Cap., Disc., .01μf	311-012
C7	Cap., 300μf, 6v	316-061
C8	Cap., 25μf, 10v	316-041
C9	Cap., .002μf	311-017
C10	Cap., Disc., .002μf	311-017
C11	Cap., Disc., .002μf	311-017
C12	Cap., Disc., .002μf	311-017
C13	Cap., Disc., .01μf	311-012
C14	Cap., 25μf, 10v	316-041
CR1	Diode, 1N914	376-061
CR2	Diode, 1N914	376-061
CR3	Diode, 1N914	376-061
CR4	Diode, 1N914	376-061
CR5	Diode, 1N914	376-061
CR6	Diode, 1N914	376-061
CR7	Diode, 1N914	376-061
CR8	Diode, 1N751A	374-022
CR9	Diode, 1N4005	376-034
CR10	Diode, 1N914	376-061
CR11	Diode, 1N753A	374-058
CR12	Diode, 1N914	376-061
CR13	Diode, 1N914	376-061
CR14	Diode, 1N914	376-061
CR15	Diode, 1N914	376-061
CR16	Diode, 1N914	376-061
CR17	Diode, 1N4005	376-034
Q1	Transistor, DN2521	A 11748
Q2	Transistor, P35201	A 11747
Q3	Transistor, 2N1303	663-011
Q4	Transistor, 2N3053	663-062
Q5	Transistor, 57764	A 11713
Q6	Transistor, 2N1303	663-011
Q7	Transistor, 2N1303	663-011
Q8	Transistor, 2N3053	663-062
Q9	Transistor, P35201	A 11747
Q10	Transistor, 57764	A 11713

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
	5-3 FILAMENT & ANODE SUPPLY Continued	
Q11	Transistor, P35201	A 11747
Q12	Transistor, 2N3053	663-062
Q13	Transistor, 2N1303	663-011
Q14	Transistor, 2N3053	663-062
R1	Resistor, 510K, 1/2W, 5%	596-514
R2	Resistor, 20K, 1/4W, 5%	595-203
R3	Resistor, 2K, 1/4W, 5%	595-202
R4	Potentiometer 20K	551-034
R5	Resistor, 7.5K, 1/4W, 5%	595-752
R6	Resistor, 10Ω, 1/4W, 5%	595-100
R7	Potentiometer 20K	551-034
R8	Resistor, 20K, 1/4W, 5%	595-203
R9	Resistor, 20K, 1/4W, 5%	595-203
R10	Resistor, 1.5K, 1/4W, 5%	595-152
R11	Resistor, 820Ω, 1/4W, 5%	595-821
R12	Potentiometer 20K	551-034
R13	Resistor, 2K, 1/4W, 5%	595-202
R14	Resistor, 160Ω, 1/4W, 5%	595-161
R15	Resistor, 300Ω, 1/4W, 5%	595-301
R16	Resistor, 100Ω, 1/4W, 5%	595-101
R17	Resistor, 5.1K, 1/4W, 5%	595-512
R18	Resistor, 680Ω, 1/4W, 5%	595-681
R19	Resistor, 1K, 1/4W, 5%	595-102
R20	Resistor, 1.5K, 1/4W, 5%	595-152
R21	Resistor, 1K, 1/4W, 5%	595-102
R22	Resistor, 120Ω, 1/4W, 5%	595-121
R23	Resistor, 510Ω, 1/4W, 5%	595-511
R24	Resistor, 2 Meg., 1/4W, 5%	595-205
R25	Resistor, 10K, 1/4W, 5%	595-103
R26	Resistor, 330K, 1/4W, 5%	595-334
R27	Resistor, 33K, 1/4W, 5%	595-333
R28	Resistor, 150Ω, 1/2W, 5%	596-151
R29	Resistor, 0.24Ω, 2W, 5%, WW	610-087
R30	Resistor, 0.24Ω, 2W, 5%, WW	610-087
R31	Resistor, 90.9Ω, 1/2W, 1%, MF	618-035
R32	Resistor, 51Ω, 1/4W, 5%	595-510
R33	Potentiometer 100Ω	551-036
R34	Resistor, 442Ω, 1/2W, 1%, MF	618-041
R35	Resistor, 1.5K, 1/4W, 5%	595-152
R36	Resistor, 51Ω, 1/4W, 5%	595-510
R37	Resistor, 200Ω, 1/4W, 5%	595-201
R38	Resistor, 220Ω, 1/4W, 5%	595-221
R39	Resistor, 100Ω, 1/4W, 5%	595-101
R40	Resistor, 100Ω, 1/4W, 5%	595-101
R41	Resistor, 51Ω, 1/4W, 5%	595-510
R42	Resistor, 680Ω, 1/4W, 5%	595-681
R43	Resistor, 2K, 1/4W, 5%	595-202
R44	Resistor, 2.4K, 1/4W, 5%	595-242
R45	Resistor, 1.5K, 1/4W, 5%	595-152

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-3 FILAMENT & ANODE SUPPLY Continued		
R46	Resistor, 6.2K, 1/2W, 5%	596-622
R47	Resistor, 51Ω, 1/4W, 5%	595-510
R48	Resistor, 24K, 1/4W, 5%	595-243
R49	Resistor, 100Ω, 1/4W, 5%	595-101
R50	Resistor, 4.02K, 1/2W, 1% MF, 20PPM/°C	618-047
R51	Resistor, 68K, 1/4W, 5%	595-683
R52	Resistor, 15.4K, 1/2W, 5%, MF	618-072
R53	Resistor, 560Ω, 1/4W, 5%	595-561
R54	Resistor, 5.1K, 1/2W, 5%	596-512
R55	Resistor, 47K, 1/4W, 5%	595-473
R56	Resistor, 330Ω, 1/4W, 5%	595-331
R57	Resistor, 68Ω, 1/4W, 5%	595-681
R58	Resistor, 100Ω, 1/4W, 5%	595-101
R59	Resistor, 51K, 1/4W, 5%	595-513
R60	Resistor, 20K, 1/4W, 5%	595-203
5-4 MARKER BOARD		
C1	Cap., Disc., .002μf	311-017
C2	Cap., Disc., .01μf	311-012
C3	Cap., Disc., .002μf	311-017
C4	Cap., Disc., .002μf	311-017
C5	Cap., Disc., .002μf	311-017
C6	Cap., Disc., .002μf	311-017
CR1	Diode, 1N914	376-061
CR2	Diode, 1N914	376-061
CR3	Diode, 1N914	376-061
CR4	Diode, 1N914	376-061
CR5	Diode, 1N914	376-061
CR6	Diode, 1N914	376-061
CR7	Diode, 1N914	376-061
CR8	Diode, 1N914	376-061
CR9	Diode, 1N914	376-061
CR10	Diode, 1N914	376-061
CR11	Diode, 1N914	376-061
CR12	Diode, 1N914	376-061
CR13	Diode, 1N914	376-061
CR14	Diode, 1N914	376-061
CR15	Diode, 1N914	376-061
CR16	Diode, 1N914	376-061
CR17	Diode, 1N914	376-061
CR18	Diode, 1N914	376-061
CR19	Diode, 1N914	376-061
CR20	Diode, 1N914	376-061
CR21	Diode, 1N914	376-061
CR22	Diode, 1N914	376-061
CR23	Diode, 1N914	376-061
CR24	Diode, 1N914	376-061

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-4 MARKER BOARD Continued		
CR25	Diode, 1N914	376-061
CR26	Diode, 1N914	376-061
CR27	Diode, 1N914	376-061
CR28	Diode, 1N914	376-061
CR29	Diode, 1N914	376-061
CR30	Diode, 1N914	376-061
CR31	Diode, 1N914	376-061
CR32	Diode, 1N914	376-061
CR33	Diode, 1N914	376-061
CR34	Diode, 1N914	376-061
CR35	Diode, 1N914	376-061
CR36	Diode, 1N914	376-061
Q1	Transistor, DN2521	A 11748
Q2	Transistor, 2N3053	663-062
Q3	Transistor, 2N966	663-032
Q4	Transistor, 2N966	663-032
Q5	Transistor, 2N706A	663-022
Q6	Transistor, DN2521	A 11748
Q7	Transistor, 2N3053	663-062
Q8	Transistor, 2N966	663-032
Q9	Transistor, 2N966	663-032
Q10	Transistor, DN2521	A 11748
Q11	Transistor, 2N3053	663-062
Q12	Transistor, 2N966	663-032
Q13	Transistor, 2N966	663-032
Q14	Transistor, DN2521	A 11748
Q15	Transistor, 2N3053	663-062
Q16	Transistor, 2N966	663-032
Q17	Transistor, 2N966	663-032
Q18	Transistor, DN2521	A 11748
Q19	Transistor, 2N3053	663-062
Q20	Transistor, 2N966	663-032
Q21	Transistor, 2N966	663-032
R1	Resistor, 10K, 1/4W, 5%	595-103
R2	Resistor, 5.1K, 1/4W, 5%	595-512
R3	Resistor, 51Ω, 1/4W, 5%	595-510
R4	Resistor, 10K, 1/4W, 5%	595-103
R5	Resistor, 100Ω, 1/4W, 5%	595-101
R6	Resistor, 5.1K, 1/4W, 5%	595-512
R7	Resistor, 100Ω, 1/4W, 5%	595-101
R8	Resistor, 1K, 1/4W, 5%	595-102
R9	Resistor, MF, 2.43K, 1/4W, 1%	618-045
R10	Resistor, 100Ω, 1/4W, 5%	595-101
R11	Resistor, 510Ω, 1/4W, 5%	595-511
R12	Resistor, MF, 7.50K, 1/2W, 1%	618-054
R13	Resistor, 100Ω, 1/4W, 5%	595-101
R14	Resistor, 100Ω, 1/4W, 5%	595-101
R15	Resistor, 510Ω, 1/4W, 5%	595-511
R16	Resistor, 11K	595-113

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-4 MARKER BOARD Continued		
R17	Resistor, MF, 7.50K, 1/2W, 1%	618-054
R18	Resistor, 130K, 1/4W, 5%	595-134
R19	Resistor, 8.2K, 1/4W, 5%	595-822
R20	Resistor, 11K	595-113
R21	Resistor, 1.3K, 1/4W, 5%	595-132
R22	Resistor, 8.2K, 1/4W, 5%	595-822
R23	Resistor, 510Ω, 1/4W, 5%	595-511
R24	Resistor, 510Ω, 1/4W, 5%	595-511
R25	Resistor, 10K, 1/4W, 5%	595-103
R26	Resistor, 5.1K, 1/4W, 5%	595-512
R27	Resistor, 51Ω, 1/4W, 5%	595-510
R28	Resistor, 10K, 1/4W, 5%	595-103
R29	Resistor, 100Ω, 1/4W, 5%	595-101
R30	Resistor, 5.1K, 1/4W, 5%	595-512
R31	Resistor, 100Ω, 1/4W, 5%	595-101
R32	Resistor, 1K, 1/4W, 5%	595-102
R33	Resistor, MF, 2.43K, 1/4W, 1%	618-045
R34	Resistor, 100Ω, 1/4W, 5%	595-101
R35	Resistor, 510Ω, 1/4W, 5%	595-511
R36	Resistor, MF, 7.50K, 1/2W, 1%	618-054
R37	Resistor, 100Ω, 1/4W, 5%	595-101
R38	Resistor, 100Ω, 1/4W, 5%	595-101
R39	Resistor, 510Ω, 1/4W, 5%	595-511
R40	Resistor, 11K	595-113
R41	Resistor, MF, 7.50K, 1/2W, 1%	618-054
R42	Resistor, 10K, 1/4W, 5%	595-103
R43	Resistor, 5.1K, 1/4W, 5%	595-512
R44	Resistor, 51Ω, 1/4W, 5%	595-510
R45	Resistor, 10K, 1/4W, 5%	595-103
R46	Resistor, 100Ω, 1/4W, 5%	595-101
R47	Resistor, 5.1K, 1/4W, 5%	595-512
R48	Resistor, 100Ω, 1/4W, 5%	595-101
R49	Resistor, 1K, 1/4W, 5%	595-102
R50	Resistor, MF, 2.43K, 1/4W, 1%	618-045
R51	Resistor, 100Ω, 1/4W, 5%	595-101
R52	Resistor, 510Ω, 1/4W, 5%	595-511
R53	Resistor, MF, 7.50K, 1/2W, 1%	618-054
R54	Resistor, 100Ω, 1/4W, 5%	595-101
R55	Resistor, 100Ω, 1/4W, 5%	595-101
R56	Resistor, 510Ω, 1/4W, 5%	595-511
R57	Resistor, 11K	595-113
R58	Resistor, MF, 7.50K, 1/2W, 1%	618-054
R59	Resistor, 10K, 1/4W, 5%	595-103
R60	Resistor, 5.1K, 1/4W, 5%	595-512
R61	Resistor, 51Ω, 1/4W, 5%	595-510
R62	Resistor, 10K, 1/4W, 5%	595-103
R63	Resistor, 100Ω, 1/4W, 5%	595-101
R64	Resistor, 5.1K, 1/4W, 5%	595-512
R65	Resistor, 100Ω, 1/4W, 5%	595-101

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-4 MARKER BOARD Continued		
R66	Resistor, 1K, 1/4W, 5%	595-102
R67	Resistor, MF, 2.43K, 1/4W, 1%	618-045
R68	Resistor, 100Ω, 1/4W, 5%	595-101
R69	Resistor, 510Ω, 1/4W, 5%	595-511
R70	Resistor, MF, 7.50K, 1/2W, 1%	618-054
R71	Resistor, 100Ω, 1/4W, 5%	595-101
R72	Resistor, 100Ω, 1/4W, 5%	595-101
R73	Resistor, 510Ω, 1/4W, 5%	595-511
R74	Resistor, 11K	595-113
R75	Resistor, MF, 7.50K, 1/2W, 1%	618-054
R76	Resistor, 10K, 1/4W, 5%	595-103
R77	Resistor, 5.1K, 1/4W, 5%	595-512
R78	Resistor, 51Ω, 1/4W, 5%	595-510
R79	Resistor, 10K, 1/4W, 5%	595-103
R80	Resistor, 100Ω, 1/4W, 5%	595-101
R81	Resistor, 5.1K, 1/4W, 5%	595-512
R82	Resistor, 100Ω, 1/4W, 5%	595-101
R83	Resistor, 1K, 1/4W, 5%	595-102
R84	Resistor, MF, 2.43K, 1/4W, 1%	618-045
R85	Resistor, 100Ω, 1/4W, 5%	595-101
R86	Resistor, 510Ω, 1/4W, 5%	595-511
R87	Resistor, MF, 7.50K, 1/2W, 1%	618-054
R88	Resistor, 100Ω, 1/4W, 5%	595-101
R89	Resistor, 100Ω, 1/4W, 5%	595-101
R90	Resistor, 510Ω, 1/4W, 5%	595-511
R91	Resistor, 11K	595-113
R92	Resistor, MF, 7.50K, 1/2W, 1%	618-054
5-5 SWEEP AMPLIFIER		
C1	Cap., Disc., .01μf, 600v	311-012
C2	Cap., Disc., .002μf, 1kv	311-017
C3	Cap., Disc., 180pf, 1kv	311-040
C4	Cap., Disc., .002μf, 1kv	311-017
C5	Cap., Disc., .002μf, 1kv	311-017
C6	Cap., Disc., .150pf, 1kv	311-008
C7	Cap., Disc., .002μf, 1kv	311-017
C8	Cap., Disc., .01μf, 600v	311-012
C9	Cap., Disc., .01μf, 600v	311-012
C10	Cap., Disc., .01μf, 600v	311-012
C11	Cap., Disc., .005μf, 1kv	311-011
C12	Cap., Disc., 20pf, 1kv	311-002
C13	Cap., Disc., .002μf, 1kv	311-017
C14	Cap., Disc., 500pf, 1kv	311-009
C15	Cap., Disc., 500pf, 1kv	311-009
C16	Cap., Disc., 100pf, 1kv	311-007
C17	Cap., Disc., .002μf, 1kv	311-017
C18	Cap., Disc., .01μf, 600v	311-012
C19	Cap., Disc., .005μf, 1kv	311-011

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-5 SWEEP AMPLIFIER Continued		
C20	Cap., Disc., 20pf, 1kv	311-002
C21	Cap., Disc., .01μf, 600v	311-012
C22	Cap., Disc., 50pf, 1kv	311-006
C23	Cap., Disc., .01μf, 600v	311-012
C24	Cap., Disc., 150pf, 1kv	311-008
C25	Cap., Disc., .01μf, 600v	311-012
C26	Cap., Disc., .002μf, 1kv	311-017
C27	Cap., Disc., .01μf, 600v	311-012
C28	Cap., Disc., .01μf, 600v	311-012
C29	Cap., Disc., 330pf, 1kv	311-029
C30	Cap., Disc., 25μf, 25v	316-028
C31	Cap., Disc., 25μf, 25v	316-028
C32	Cap., Disc., 15μf, 50v	316-062
C33	Cap., Disc., 25μf, 25v	316-028
C34	Cap., Disc., 15μf, 50v	316-062
CR1	Diode, 1N914	376-061
CR2	Diode, 1N914	376-061
CR3	Diode, 1N751A	374-022
CR4	Diode, 1N751A	374-022
CR5	Diode, 1N914	376-061
CR6	Diode, 1N914	376-061
CR7	Diode, 1N969B	374-063
CR8	Diode, 1N914	376-061
CR9	Diode, 1N914	376-061
CR10	Diode, 1N914	376-061
CR11	Diode, 1N914	376-061
CR12	Diode, 1N914	376-061
CR13	Diode, 1N914	376-061
CR14	Diode, 1N914	376-061
CR15	Diode, 1N914	376-061
CR16	Diode, 1N914	376-061
CR17	Diode, 1N914	376-061
CR18	Diode, 1N914	376-061
CR19	Diode, 1N914	376-061
Q1	Transistor, P35201	A 11747
Q2	Transistor, DN2521	A 11748
Q3	Transistor, P35201	A 11747
Q4	Transistor, DN2521	A 11748
Q5	Transistor, DN2521	A 11748
Q6	Transistor, P35201	A 11747
Q7	Transistor, P35201	A 11747
Q8	Transistor, 2N3053	663-062
Q9	Transistor, DN2521	A 11748
Q10	Transistor, P35201	A 11747
Q11	Transistor, P35201	A 11747
Q12	Transistor, 2N3053	663-062
R1	Resistor, 681Ω, 1/2W, 1%, MF	618-042
R2	Resistor, 2K, 1/4W, 5%	595-202

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-5 SWEEP AMPLIFIER Continued		
R3	Resistor, 51Ω, 1/4W, 5%	595-510
R4	Resistor, 2.21K, 1/2W, 1%, MF	618-044
R5	Resistor, 3.6K, 1W, 5%	597-362
R6	Resistor, 2K, 1/4W, 5%	595-202
R7	Resistor, 51Ω, 1/4W, 5%	595-510
R8	Resistor, 2.21K, 1/2W, 1%, MF	618-044
R9	Resistor, 3.6K, 1W, 5%	597-362
R10	Resistor, 180Ω, 1/4W, 5%	595-181
R11	Resistor, 4.02K, 1/2W, 1%, MF 20PPM/°C	618-047
R12	Resistor, 681Ω, 1/2W, 1%, MF	618-042
R13	Resistor, 180Ω, 1/4W, 5%	595-181
R14	Resistor, 4.02K, 1/2W, 1%, MF 20PPM/°C	618-047
R15	Resistor, 4.02K, 1/2W, 1%, MF 20PPM/°C	618-047
R16	Resistor, 154K, 1/2W, 1%, MF	618-065
R17	Resistor, 620Ω, 1/4W, 5%	595-621
R18	Resistor, 160Ω, 1/4W, 5%	595-161
R19	Resistor, 390K, 1/4W, 5%	595-394
R20	Potentiometer 20K	551-034
R21	Resistor, 4.02K, 1/2W, 1%, MF 20PPM/°C	618-047
R22	Resistor, 75Ω, 1/4W, 5%	595-750
R23	Resistor, 100K, 1/2W, 1%, MF	618-024
R24	Resistor, 5.62K, 1/2W, 1%, MF	618-052
R25	Resistor, 15K, 1/4W, 5%	595-153
R26	Resistor, 680Ω, 1/4W, 5%	595-681
R27	Resistor, 330Ω, 1/4W, 5%	595-331
R28	Resistor, 160Ω, 1/4W, 5%	595-161
R29	Resistor, 154K, 1/2W, 1%, MF	618-065
R30	Resistor, 620Ω, 1/4W, 5%	595-621
R31	Potentiometer 100Ω	551-036
R32	Resistor, 4.02K, 1/2W, 1%, MF 20PPM/°C	618-047
R33	Resistor, 51Ω, 1/4W, 5%	595-510
R34	Resistor, 330K, 1/4W, 5%	595-334
R35	Resistor, 4.02K, 1/2W, 1%, MF 20PPM/°C	618-047
R36	Resistor, 270Ω, 1/4W, 5%	595-271
R37	Resistor, 19.6K, 1/2W, 1%, MF	618-060
R38	Resistor, 160Ω, 1/4W, 5%	595-161
R39	Resistor, 56.2Ω, 1/2W, 1%, MF	618-031
R40	Resistor, 64.9Ω, 1/2W, 1%, MF	618-032
R41	Resistor, 73.2Ω, 1/2W, 1%, MF	618-033
R42	Resistor, 82.5Ω, 1/2W, 1%, MF	618-034
R43	Resistor, 93.1Ω, 1/2W, 1%, MF	618-036
R44	Resistor, 110Ω, 1/2W, 1%, MF	618-037
R45	Resistor, 127Ω, 1/2W, 1%, MF	618-038

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-5 SWEEP AMPLIFIER Continued		
R46	Resistor, 150Ω, 1/2W, 1%, MF	618-039
R47	Resistor, 200Ω, 1/2W, 1%, MF	618-021
R48	Resistor, 1K, 1/2W, 1%, MF	618-007
R49	Resistor, 1K, 1/2W, 1%, MF	618-007
R50	Resistor, 3.01K, 1/2W, 1%, MF	618-018
R51	Resistor, 3.01K, 1/2W, 1%, MF	618-018
R52	Resistor, 3.01K, 1/2W, 1%, MF	618-018
R53	Resistor, 12.1K, 1/2W, 1%, MF	618-056
R54	Resistor, 18.2K, 1/2W, 1%, MF	618-059
R55	Resistor, 27.4K, 1/2W, 1%, MF	618-063
R56	Resistor, 41.2K, 1/2W, 1%, MF	618-064
R57	Resistor, 6.49K, 1/2W, 1%, MF	618-053
R58	Potentiometer, 50K	551-037
R59	Potentiometer, 50K	551-037
R60	Potentiometer, 50K	551-037
R61	Potentiometer, 50K	551-037
R62	Potentiometer, 50K	551-037
R63	Potentiometer, 50K	551-037
R64	Potentiometer, 50K	551-037
R65	Potentiometer, 50K	551-037
R66	Potentiometer, 50K	551-037
R67	Potentiometer, 10K	540-014
R68	Potentiometer, 10K	540-014
R69	See Calibration Procedure	
R70	See Calibration Procedure	
R71	Resistor, 2K, 1/4W, 5%	595-202
R72	Potentiometer, 2K (Borg)	551-038
R73	Resistor, 1.05K, 1W, 1%	619-002
R74	Resistor, 12.7K, 1/2W, 1%, MF	618-057
R75	Resistor, 12.7K, 1/2W, 1%, MF	618-057
R76	Resistor, 10K, 1/4W, 5%	595-103
R77	Resistor, 59.0K, 1/2W, 1%, MF	618-051
R78	Resistor, 16K, 1/4W, 5%	595-163
R79	Resistor, 3K, 1/4W, 5%	595-302
R80	Resistor, 510Ω, 1/4W, 5%	595-511
R81	Resistor, 51Ω, 1/4W, 5%	595-510
R82	Resistor, 22K, 1/4W, 5%	595-223
R83	Resistor, 1.5K, 1/4W, 5%	595-152
R84	Resistor, 270Ω, 1/4W, 5%	595-271
R85	Resistor, 100Ω, 1/4W, 5%	595-101
5-6 SWEEP GENERATOR		
C1	Cap., Disc., .002μf	311-017
C2	Cap., Disc., 500pf	311-009
C3	Cap., Disc., .01μf	311-012
C4	Cap., Disc., .01μf	311-012
C5	Cap., Disc., .002μf	311-017
C6	Cap., Disc., .002μf	311-017

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-6 SWEEP GENERATOR Continued		
C7	Cap., Disc., 500pf	511-009
C8	Cap., Disc., 10pf, 5% (Dip Mica)	311-051
C9	Cap., Disc., .01μf	311-012
C10	Cap., Disc., .01μf	311-012
C11	Cap., Disc., .01μf	311-012
C12	Cap., Disc., .01μf	311-012
C13	Cap., Disc., 25μf, 25v	316-028
C14	Cap., Disc., 15μf, 50v	316-062
C15	Cap., Disc., 15μf, 50v	316-062
C16	Cap., Disc., 25μf, 25v	316-028
C17	Cap., Disc., 10pf	311-011
C18	Cap., Disc., .01μf	311-012
C19	Cap., Disc., .002μf	311-017
C20	Cap., Disc., .002μf	311-017
C21	Cap., Disc., .01μf	311-012
C22	Cap., Disc., 25μf, 10v	316-041
C23	Cap., Disc., .01μf	311-012
C24	Cap., Disc., 250pf	311-004
C25	Cap., Disc., .002μf	311-017
C26	Cap., Disc., .01μf	311-012
C27	Cap., Disc., 10pf	311-011
CR1	Diode, 1N914	376-061
CR2	Diode, 1N914	376-061
CR3	Diode, 1N914	376-061
CR4	Diode, 1N914	376-061
CR5	Diode, 1N914	376-061
CR6	Diode, 1N914	376-061
CR7	Diode, 1N914	376-061
CR8	Diode, 1N914	376-061
CR9	Diode, 1N914	376-061
CR10	Diode, 1N914	376-061
CR11	Diode, 1N914	376-061
CR12	Diode, 1N914	376-061
CR13	Diode, 1N914	376-061
CR14	Diode, 1N914	376-061
CR15	Diode, 1N914	376-061
CR16	Diode, 1N914	376-061
CR17	Diode, 1N914	376-061
CR18	Diode, 1N914	376-061
CR19	Diode, 1N4442	376-064
CR20	Diode, 1N914	376-061
CR21	Diode, 1N746A	374-017
CR22	Diode, 1N914	376-061
CR23	Diode, 1N914	376-061
CR24	Diode, 1N914	376-061
CR25	Diode, 1N914	376-061
CR26	Diode, 1N914	376-061

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-6 SWEEP GENERATOR Continued		
CR27	Diode, 1N914	376-061
CR28	Diode, 1N914	376-061
Q1	Transistor, P35201	A 11747
Q2	Transistor, 2N720A	663-074
Q3	Transistor, P35201	A 11747
Q4	Transistor, P35201	A 11747
Q5	Transistor, P35201	A 11747
Q6	Transistor, S7764 E-H Special	A 11713
Q7	Transistor, P35201	A 11747
Q8	Transistor, S7764 E-H Special	A 11713
Q9	Transistor, 2N3053	663-062
Q10	Transistor, P35201	A 11747
Q11	Transistor, P35201	A 11747
Q12	Transistor, P35201	A 11747
Q13	Transistor, P35201	A 11747
Q14	Transistor, P35201	A 11747
Q15	Transistor, DN2521	A 11748
Q16	Transistor, 2N706A	663-022
Q17	Transistor, P35201	A 11747
R1	Resistor, 100Ω, 1/4W, 5%	595-101
R2	Resistor, 270Ω, 1/4W, 5%	595-271
R3	Resistor, 300Ω, 1/4W, 5%	595-301
R4	Resistor, 6.8K, 1/4W, 5%	595-682
R5	Resistor, 5.1K, 1/4W, 5%	595-512
R6	Resistor, 100K, 1/4W, 5%	595-104
R7	Resistor, 6.2K, 1/4W, 5%	595-622
R8	Resistor, 68K, 1/4W, 5%	595-683
R9	Resistor, 3.9K, 1/4W, 5%	595-392
R10	Resistor, 680Ω, 1/4W, 5%	595-681
R11	Resistor, 18K, 1/4W, 5%	595-183
R12	Resistor, 36K, 1/4W, 5%	595-363
R13	Resistor, 3K, 1/4W, 5%	595-302
R14	Resistor, 680Ω, 1/4W, 5%	595-681
R15	Resistor, 10K, 1/4W, 5%	595-103
R16	Resistor, 10K, 1/4W, 5%	595-103
R17	Resistor, 39K, 1/4W, 5%	595-393
R18	Resistor, 100K, 1/4W, 5%	595-104
R19	Resistor, 39K, 1/4W, 5%	595-393
R20	Resistor, 680Ω, 1/4W, 5%	595-681
R21	Resistor, 3.3K, 1/2W, 5%	596-332
R22	Resistor, 1K, 1/4W, 5%	595-102
R23	Resistor, 100Ω, 1/4W, 5%	595-101
R24	Resistor, 20K, 1/4W, 5%	595-203
R25	Resistor, 15K, 1/4W, 5%	595-153
R26	Resistor, 4.3K, 1/2W, 5%	596-432
R27	Resistor, 2.7K, 1/4W, 5%	595-272

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-6 SWEEP GENERATOR Continued		
R28	Resistor, 1.2K, 1/4W, 5%	595-122
R29	Resistor, 100Ω, 1/4W, 5%	595-101
R30	Resistor, 10M, 1/4W, 5%	595-106
R31	Resistor, 51Ω, 1/4W, 5%	595-510
R32	Resistor, 2.2Ω, 2W, 5%, WW	610-091
R33	Resistor, 1M, 1/4W, 5%	595-105
R34	Resistor, 51Ω, 1/4W, 5%	595-510
R35	Resistor, 4.3K, 1/4W, 5%	595-432
R36	Resistor, 11K, 1/4W, 5%	595-113
R37	Resistor, 5.1K, 1/4W, 5%	595-512
R38	Resistor, 680Ω, 1/4W, 5%	595-681
R39	Resistor, 820Ω, 1/4W, 5%	595-821
R40	Resistor, 5.1K, 1/4W, 5%	595-512
R41	Resistor, 3.6K, 1/2W, 5%	596-362
R42	Resistor, 3.6K, 1/2W, 5%	596-362
R43	Resistor, 47K, 1/4W, 5%	595-473
R44	Resistor, 12K, 1/4W, 5%	595-123
R45	Resistor, 180Ω, 1/4W, 5%	595-181
R46	Resistor, 1.8K, 1/4W, 5%	595-182
R47	Resistor, 10K, 1/4W, 5%	595-103
R48	Resistor, 510K, 1/4W, 5%	595-514
R49	Resistor, 3K, 1/4W, 5%	595-302
R50	Resistor, 1.8K, 1/4W, 5%	595-182
R51	Resistor, 15K, 1/4W, 5%	595-153
R52	Resistor, 5.1K, 1/4W, 5%	595-512
R53	Resistor, 10K, 1/4W, 5%	595-103
R54	Resistor, 680Ω, 1/4W, 5%	595-681
R55	Resistor, 3.6K, 1/2W, 5%	596-362
R56	Resistor, 680Ω, 1/4W, 5%	595-681
R57	Resistor, 3.6K, 1/2W, 5%	596-362
R58	Resistor, 5.1K, 1/4W, 5%	595-512
R59	Resistor, 7.5K, 1/2W, 5%	596-752
R60	Resistor, 3.74K, 1/2W, 1%, MF	618-046
R61	Resistor, 7.50K, 1/2W, 1%, MF	618-054
R62	Resistor, 11K, 1/4W, 5%	595-113
R63	Resistor, 330Ω, 1/4W, 5%	595-331
R64	Resistor, 4.02K, 1/2W, 1%, MF 20PPM/°C	618-047
R65	Potentiometer (Borg) 100Ω	551-036
R66	Resistor, 4.02K, 1/2W, 1%, MF 20PPM/°C	618-047
R67	Resistor, 10K, 1/4W, 5%	595-103
R68	Resistor, 4.42K, 1/2W, 1%, MF	618-050
R69	Resistor, 1.2K, 1/4W, 5%	595-122
R70	Resistor, 180Ω, 1/4W, 5%	595-181
R71	Resistor, 2K, 1/4W, 5%	595-202
R72	Resistor, 4.75K, 1/2W, 1%, MF	618-049
R73	Resistor, 330Ω, 1/4W, 5%	595-331
R74	Resistor, 33Ω, 1/4W, 5%	595-330

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-6 SWEEP GENERATOR Continued		
R75	Resistor, 2K, 1/4W, 5%	595-202
R76	Resistor, 4.02K, 1/2W, 1%, MF 20PPM/°C	618-047
R77	Potentiometer (Borg) 100Ω	551-036
R78	Resistor, 4.02K, 1/2W, 1%, MF 20PPM/°C	618-047
R79	Resistor, 4.3K, 1W, 5%	597-432
R80	Resistor, 180Ω, 1/4W, 5%	595-181
V1	Nuvistor	670-035
5-7 HIGH VOLTAGE REGULATOR		
C1	Cap., 20μf, 250v	316-048
C2	Cap., .1μf, 75v	311-014
C3	Cap., .1μf, 75v	311-014
C4	Cap., .1μf, 75v	311-014
C5	Cap., 10μf, 100v	316-032
C6	Cap., 25μf, 25v	316-028
C7	Cap., 500pf, 1kv, 10%	311-009
C8	Cap., 50pf, 3kv, 20%	311-050
C9	Cap., 500pf, 3kv, 20%	311-049
C10	Cap., 100pf, 3kv, 20%	311-048
C11	Cap., 150pf, 1kv, 10%	311-008
C12	Cap., 10μf, 100v	316-032
C13	Cap., 15pf, 1kv, 10%	311-035
C14	Cap., 15pf, 1kv, 10%	311-035
C15	Cap., 15pf, 1kv, 10%	311-035
C16	Cap., 15pf, 1kv, 10%	311-035
CR1	Diode, 1N4005	376-034
CR2	Diode, 1N3805	374-060
CR3	Diode, 1N914B	376-022
CR4	Diode, 1N3805	374-060
K1	Relay, F4-10005	584-006
R1	Resistor, 100Ω, 1/2W, 5%	596-101
R2	Resistor, 1.8K, 2W, 5%	598-182
R3	Resistor, 1.8K, 2W, 5%	598-182
R4	Resistor, 240K, 1/2W, 5%	596-244
R5	Resistor, 10Ω, 1/2W, 5%	596-100
R6	Resistor, 27K, 2W, 5%	598-273
R7	Resistor, 150K, 1/2W, 5%	596-154
R8	Resistor, 100Ω, 1/2W, 5%	596-101
R9	Resistor, 100Ω, 1/2W, 5%	596-101
R10	Resistor, 100Ω, 1/2W, 5%	596-101
R11	Resistor, 330Ω, 1/2W, 5%	596-331
R12	Resistor, 100Ω, 1/2W, 5%	596-101
R13	Resistor, 100Ω, 1/2W, 5%	596-101
R14	Resistor, 330Ω, 1/2W, 5%	596-331
R15	Resistor, 100Ω, 1/2W, 5%	596-101

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-7 HIGH VOLTAGE REGULATOR Continued		
R16	Resistor, 100Ω, 1/2W, 5%	596-101
R17	Resistor, 330Ω, 1/2W, 5%	596-331
R18	Resistor, 100Ω, 1/2W, 5%	596-101
R19	Resistor, 1K, 1/2W, 5%	596-102
R20	Resistor, 100Ω, 1/2W, 5%	596-101
R21	Resistor, 100Ω, 1/2W, 5%	596-101
R22	Resistor, 100Ω, 1/2W, 5%	596-101
R23	Resistor, 3K, 1/2W, 5%	596-302
R24	Resistor, 3K, 1/2W, 5%	596-302
R25	Resistor, 51Ω, 1/2W, 5%	596-510
R26	Resistor, 150Ω, 1/2W, 5%	596-151
R27	See Calibration Procedure	
R28	Resistor, 75K, 10W, 3%	610-085
R29	Resistor, 75K, 10W, 3%	610-085
R30	Resistor, 75K, 10W, 3%	610-085
R31	Resistor, 75K, 10W, 3%	610-085
V1	Tube, 8068	670-034
V2	Tube, 8068	670-034
V3	Tube, 8068	670-034
V4	Tube, 6GV5	670-033
5-8 HIGH VOLTAGE RECTIFIER		
CR1	Diode, 1N4005	374-034
CR2	Diode, 1N4005	374-034
CR3	Diode, 1N4005	374-034
CR4	Diode, 1N4005	374-034
CR5	Diode, 1N4005	374-034
CR6	Diode, 1N4005	374-034
CR7	Diode, 1N4005	374-034
CR8	Diode, 1N4005	374-034
CR9	Diode, 1N4005	374-034
CR10	Diode, 1N4005	374-034
CR11	Diode, 1N4005	374-034
CR12	Diode, 1N4005	374-034
CR13	Diode, 1N4005	374-034
CR14	Diode, 1N4005	374-034
CR15	Diode, 1N4005	374-034
CR16	Diode, 1N4005	374-034
R1	Resistor, 3.9M, 1/4W, 5%	595-395
R2	Resistor, 3.9M, 1/4W, 5%	595-395
R3	Resistor, 3.9M, 1/4W, 5%	595-395
R4	Resistor, 3.9M, 1/4W, 5%	595-395
R5	Resistor, 3.9M, 1/4W, 5%	595-395
R6	Resistor, 3.9M, 1/4W, 5%	595-395
R7	Resistor, 3.9M, 1/4W, 5%	595-395
R8	Resistor, 3.9M, 1/4W, 5%	595-395
R9	Resistor, 3.9M, 1/4W, 5%	595-395
R10	Resistor, 3.9M, 1/4W, 5%	595-395
R11	Resistor, 3.9M, 1/4W, 5%	595-395

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-8	HIGH VOLTAGE RECTIFIER Continued	
R12	Resistor, 3.9M, 1/4W, 5%	595-395
R13	Resistor, 3.9M, 1/4W, 5%	595-395
R14	Resistor, 3.9M, 1/4W, 5%	595-395
R15	Resistor, 3.9M, 1/4W, 5%	595-395
R16	Resistor, 3.9M, 1/4W, 5%	595-395
R17	Resistor, 100Ω, 1/2W, 5%	596-101
R18	Resistor, 51Ω, 1/4W, 5%	595-510
R19	Resistor, 51Ω, 1/4W, 5%	595-510
R20	Resistor, 51Ω, 1/4W, 5%	595-510
5-9	LOW VOLTAGE RECTIFIER	
C1	Cap., Disc., .01μf	311-012
C2	Cap., Disc., .01μf	311-012
CR1	Diode, 1N4005	376-034
CR2	Diode, 1N4005	376-034
CR3	Diode, 1N4005	376-034
CR4	Diode, 1N4005	376-034
CR5	Diode, 1N4005	376-034
CR6	Diode, 1N4005	376-034
CR7	Diode, 1N983B	374-062
CR8	Diode, 1N4005	376-034
CR9	Diode, 1N4005	376-034
CR10	Diode, 1N4005	376-034
CR11	Diode, 1N4005	376-034
CR12	Diode, 1N4005	376-034
CR13	Diode, 1N4005	376-034
CR14	Diode, 1N4005	376-034
CR15	Diode, 1N4005	376-034
CR16	Diode, 1N4005	376-034
CR17	Diode, 1N4005	376-034
M1	Elapsed Time Meter	805-002
M1	Meter Scale	A 11548
R1	Resistor, 300K, 1/2W, 5%	596-304
R2	Resistor, 300K, 1/2W, 5%	596-304
R3	Resistor, 6.8K, 1/2W, 5%	595-682
R4	Resistor, 180K, 1W, 5%	597-184
R5	Resistor, 180K, 1W, 5%	597-184
R6	Resistor, 6.8K, 1/4W, 5%	595-682
R7	Resistor, 3Meg, 1/2W, 5%	596-305
R8	Resistor, 220K, 1W, 5%	597-224
R9	Deleted	
R10	Resistor, 33K, 1/2W, 5%	596-333
5-10	LEVELER BOARD	
C1	Cap., .02μf, Mylar, Elec.	320-022
C2	Cap., .02μf, Mylar, Elec.	320-022
C3	Cap., .002μf, Cer.	311-017
C4	Cap., .002μf, Cer.	311-017
C5	Cap., 5pf, Cer.	311-018
C6	Cap., 25μf, 10v	316-041
C7	Cap., 500pf, Cer.	311-009
C8	Cap., 5pf, Cer.	311-018
C9	Cap., 150pf, Cer.	311-008
C10	Cap., 200pf, Cer.	311-028
C11	Cap., 1pf, Cer.	311-055
C12	Cap., .005μf, Cer.	311-011
C13	Cap., 25pf, Cer.	311-003
C14	Cap., 25μf, 10v	316-041
C15	Cap., 20pf, Cer.	311-002
C16	Cap., 2.2pf, Cer.	311-054
C17	Cap., 500pf, Cer.	311-009
C18	Cap., 3.3pf, Cer.	311-022
C19	Cap., .01μf, Cer.	311-012
C20	Cap., 30pf, Cer.	311-005
C21	Cap., 1μf, 25v, Elec.	316-067
C22	Cap., 100μf, 6v, Elec.	316-068
C23	Cap., 15μf, 50v, Elec.	316-062
C24	Cap., 15μf, 50v, Elec.	316-062
CR1	Diode, 1N914	376-061
CR2	Diode, 1N914	376-061
CR3	Diode, 1N914	376-061
CR4	Diode, 1N914	376-061
CR5	Diode, 1N914	376-061
CR6	Diode, 1N914	376-061
CR7	Diode, 1N914	376-061
CR8	Diode, 1N914	376-061
CR9	Diode, 1N914	376-061
CR10	Diode, 1N751A	374-022
CR11	Diode, 1N914	376-061
CR12	Diode, 1N914	376-061
CR13	Diode, 1N751A	374-022
CR14	Diode, 1N751A	374-022
CR15	Diode, 1N914	376-061
CR16	Diode, 1N914	376-061
CR17	Diode, 1N914	376-061
CR18	Diode, 1N751A	374-022
CR19	Diode, 1N751A	374-022
CR20	Diode, 1N751A	374-022
CR21	Diode, 1N751A	374-022
Q1	Transistor, DN2521	A 11748
Q2	Transistor, DN2521	A 11748
Q3	Transistor, DN2521	A 11748
Q4	Transistor, P35201	A 11747
Q5	Transistor, P35201	A 11747
Q6	Transistor, P35201	A 11747
Q7	Transistor, 2N720A	663-074
Q8	Transistor, DN2521	A 11748

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-10	LEVELER BOARD Continued	
Q9	Transistor, U-149 FET	663-077
Q10	Transistor, 2N706A	663-022
Q11	Transistor, P35201	A 11747
Q12	Transistor, 2N3053	663-062
R1	Resistor, 120K, 1/4W, 5%	595-124
R2	Resistor, 300Ω, 1/4W, 5%	595-301
R3	Resistor, 300Ω, 1/4W, 5%	595-301
R4	Resistor, 12K, 1/4W, 5%	595-123
R5	Resistor, 120K, 1/4W, 5%	595-124
R6	Resistor, 2.4K, 1/4W, 5%	595-242
R7	Resistor, 5.1K, 1/4W, 5%	595-512
R8	Resistor, 9.1K, 1/4W, 5%	595-912
R9	Potentiometer, 20K	551-034
R10	Resistor, 30.1K, 1/2W, 1%, MF	618-070
R11	Resistor, 1K, 1/4W, 5%	595-102
R12	Resistor, 30.1K, 1/2W, 1%, MF	618-070
R13	Resistor, 1K, 1/4W, 5%	595-102
R14	Resistor, 12K, 1/4W, 5%	595-123
R15	Resistor, 100Ω, 1/4W, 5%	595-101
R16	Resistor, 240K, 1/4W, 5%	595-244
R17	Resistor, 51Ω, 1/4W, 5%	595-510
R18	Resistor, 1K, 1/4W, 5%	595-102
R19	Resistor, 121K, 1/2W, 1%, MF	618-069
R20	Resistor, 1K, 1/4W, 5%	595-102
R21	Resistor, 5.1K, 1/4W, 5%	595-512
R22	Resistor, 39K, 1/4W, 5%	595-393
R23	Resistor, 2.7K, 1/4W, 5%	595-272
R24	Resistor, 10K, 1/4W, 5%	595-103
R25	Resistor, 680Ω, 1/4W, 5%	595-681
R26	Resistor, 510Ω, 1/4W, 5%	595-511
R27	Resistor, 150K, 1/4W, 5%	595-154
R28	Resistor, 51Ω, 1/4W, 5%	595-510
R29	Resistor, 100Ω, 1/4W, 5%	595-101
R30	Resistor, 10K, 1/4W, 5%	595-103
R31	Resistor, 100Ω, 1/4W, 5%	595-101
R32	Resistor, 6.2K, 1/4W, 5%	595-622
R33	Resistor, 1.3K, 1/4W, 5%	595-132
R34	Resistor, 22K, 1/4W, 5%	595-223
R35	Resistor, 1.3K, 1/4W, 5%	595-132
R36	Resistor, 2K, 1/2W, 5%	596-202
R37	Resistor, 4.3K, 1/4W, 5%	595-432
R38	Resistor, 56K, 1/4W, 5%	595-563
R39	Resistor, 23.7K, 1/2W, 1%, MF	618-071
R40	Resistor, 249K, 1/2W, 1%, MF	618-068
R41	Resistor, 1.5K, 1/2μ, 5%	596-152
R42	Resistor, 1K, 1/2W, 5%	596-102
R43	Resistor, 360K, 1/4W, 5%	595-364
R44	Resistor, 220K, 1/4W, 5%	595-224
R45	Resistor, 510Ω, 1/4W, 5%	595-511

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-10	LEVELER BOARD Continued	
R46	Resistor, 47K, 1/4W, 5%	595-473
R47	Resistor, 23.7K, 1/2W, 1%, MF	618-071
R48	Resistor, 2.4K, 1/4W, 5%	595-242
R49	Resistor, 5.1K, 1/4W, 5%	595-512
R50	Resistor, 3.6K, 1/4W, 5%	595-362
R51	Resistor, 1.2M, 1/4W, 5%	595-125
R52	Resistor, 18K, 1/4W, 5%	595-183
R53	Resistor, 220K, 1/4W, 5%	595-224
R54	Resistor, 12K, 1/4W, 5%	595-123
R55	Resistor, 5.1Ω, 1/4W, 5%	595-051
R56	Resistor, 100K, 1/4W, 5%	595-104
R57	Resistor, 51K, 1/4W, 5%	595-513
R58	Potentiometer, 20K	551-034
R59	Resistor, 2K, 1/2W, 5%	596-202
R60	Resistor, 30K, 1/4W, 5%	595-303
R61	Resistor, 11K, 1/4W, 5%	595-113
R62	Resistor, 1.3K, 1/4W, 5%	595-132
R63	Resistor, 510Ω, 1/4W, 5%	595-511
R64	Resistor, 510Ω, 1/4W, 5%	595-511
R65	Potentiometer, 20K	551-034
R66	Resistor, 51Ω, 1/4W, 5%	595-510
5-11	MISCELLANEOUS	
C101	Cap., 400μf, 200v	316-060
C102	Cap., 95μf, 500v	316-059
C103	Cap., 1500μf, 50v	316-066
C104	Cap., 1500μf, 50v	316-066
C105	Cap., 5650μf, 25v	316-058
C106	Cap., 1μf, 500v, DC	311-023
C107	Cap., .001μf	311-010
C108	Cap., 100μf, 15v	316-030
C109	Cap., 1μf, 12v, DC	311-041
C201	Cap., 10μf, 5%	316-065
C202	Cap., 1μf, 5%, Mylar	320-011
C203	Cap., .1μf, 5%, Mylar	320-007
C204	Cap., .01μf, 5%, Poly	326-006
C205	Cap., .001μf, 5%, Poly	326-005
C206	Cap., 91pf, 5%, Dip Mica	311-052
C207	See Fig 4-2	
C301	Cap., 4μf, 2kv w/Brk'ts.	316-063
C302	Cap., 4μf, 2kv w/Brk'ts.	316-063
C303	See Fig 4-2	
C304	See Fig 4-2	
C305	Cap., .01μf, 600v	311-012
CR101	Diode, 368B	376-066
CR102	Diode, 368B	376-066
CR103	Diode, 1Nj005	376-034
CR201	Diode, 1N914	376-061

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-11 MISCELLANEOUS Continued		
CR202	Diode, 1N914	376-061
CR203	Diode, 1N914	376-061
CR204	Diode, 1N914	376-061
CR205	Diode, 1N914	376-061
CR206	Diode, 1N914	376-061
CR207	Diode, 1N914	376-061
K101	Relay	A 12341
K102	Relay	A 12341
K103	Relay	A 12341
M201	Meter	A 12342
Q101	Transistor	A 11705
Q102	Transistor	663-073
Q103	Transistor	663-075
Q104	Transistor	A 11705
Q105	Transistor	A 11705
Q106	Transistor	663-035
R101	Resistor, 15Ω, 1/2W, 5%	596-150
R102	Resistor, 33K, 1/2W, 5%	596-333
R103	Resistor, 2.2K, 1/2W, 5%	596-222
R104	Resistor, 10K, 1/2W, 5%	596-103
R105	Resistor, 10K, 1/2W, 5%	596-103
R106	Resistor, 150K, 1/2W, 5%	596-154
R107	Resistor, 3.3K, 1/2W, 5%	596-332
R108	Resistor, 1Meg., 1/2W, 5%	596-105
R109	Resistor, 100Ω, 5W, WW	610-086
R110	Resistor, 20K, 20W, WW	610-090
R111	See Fig 4-2	
R201	Potentiometer, 5K	550-003
R202	Potentiometer, 50Ω	A 11865
R203	Potentiometer, Dual 25K	550-036
R204	Resistor, 5.1K, 1/4W, 5%	595-512
R205	Deleted	
R206	Resistor, 2.7K, 1/2W, 5%	596-272
R207	Resistor, 1K, 1/2W, 5%	596-102
R208	Resistor, 12K, 1/4W, 5%	595-123

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-11 MISCELLANEOUS Continued		
R209	Resistor, 100K, 1/4W, 5%	595-104
R210	Resistor, 100K, 1/4W, 5%	595-104
R211	Resistor, 100K, 1/4W, 5%	595-104
R212	Resistor, 5.1K, 1/4W, 5%	595-512
R213	Resistor, 5.1K, 1/4W, 5%	595-512
R214	Resistor, 12K, 1/4W, 5%	595-123
R215	Potentiometer, 1K	550-002
R216	Resistor, 100K, 1/4W, 5%	595-104
R217	Resistor, 4.7K, 1/4W, 5%	595-472
R218	Resistor, 8.2K, 1/4W, 5%	595-822
R219	Resistor, 240K, 1/4W, 5%	595-244
R220	Resistor, 100K, 1/4W, 5%	595-104
R221	Resistor, 100K, 1/4W, 5%	595-104
R222	See Fig 4-2	
R223	Resistor, 1.82K, 1/4W, 1%, MF	617-024
R224	Resistor, 3.01K, 1/4W, 1%, MF	617-002
R225	Resistor, 1.1K, 1/4W, 5%	595-112
R226	Resistor, 11K, 1/4W, 5%	595-113
R227	Resistor, 1K, 1/4W, 1%, MF 20 PPM/°C	617-002
R228	Resistor, 5.1K, 1/4W, 5%	595-512
R229	Resistor, 221K, 1/2W, 1%, MF	618-066
R230	Potentiometer, 5K, 10-turn	540-016
R231	Potentiometer, 5K, 10-turn	540-016
R232	Potentiometer, 5K, 10-turn	540-016
R233	Potentiometer, 5K, 10-turn	540-016
R234	Potentiometer, 5K, 10-turn	540-016
R235	Resistor, 4.02K, 1/2W, 1%, MF	618-047
R236	Resistor, 5.1K, 1/4W, 5%	595-512
R237	Potentiometer, 10K	550-012
R238	Resistor, 1.5K, 1/4W, 5%	595-152
R239	Resistor, 18K, 1/4W, 5%	595-183
R301	See Fig 4-2	
R302	Resistor, 100Ω, 1/2W, 5%	596-101
T101	Transformer	B 10579
T102	Transformer	B 10578

SECTION 6
DRAWINGS

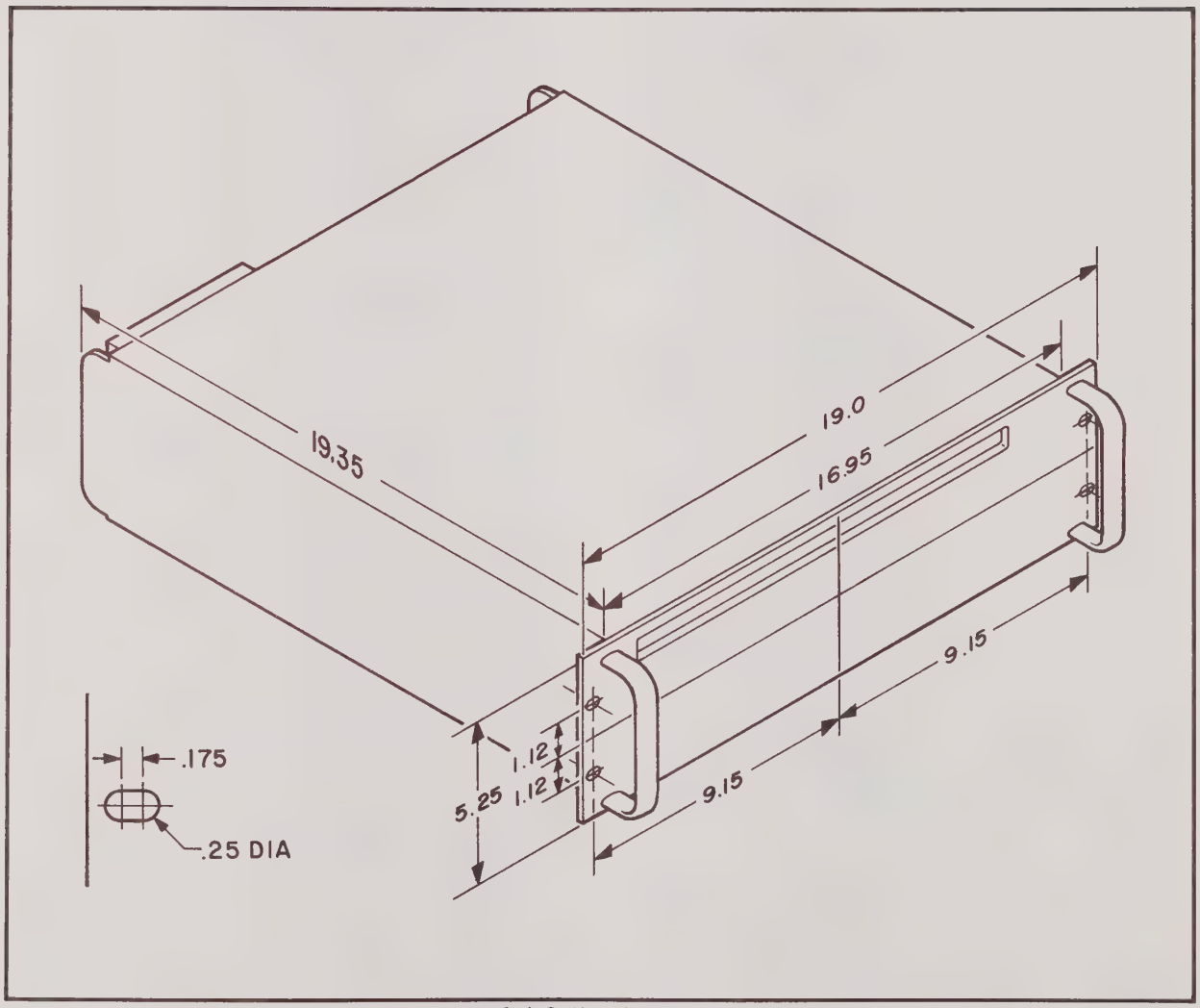


Fig 6-1 Outline Dimensions

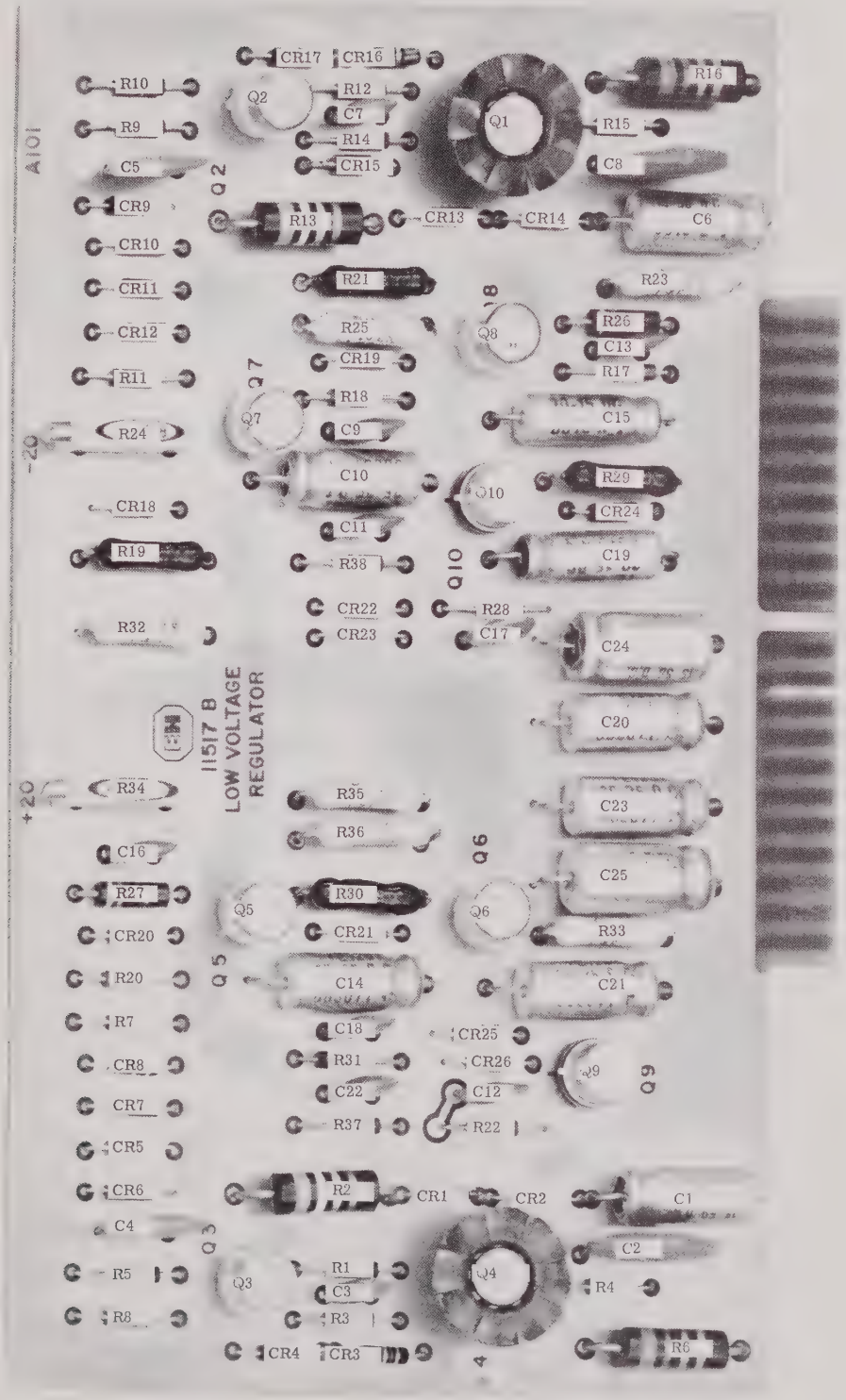


Fig 6-2 A101 Low Voltage Regulator Board

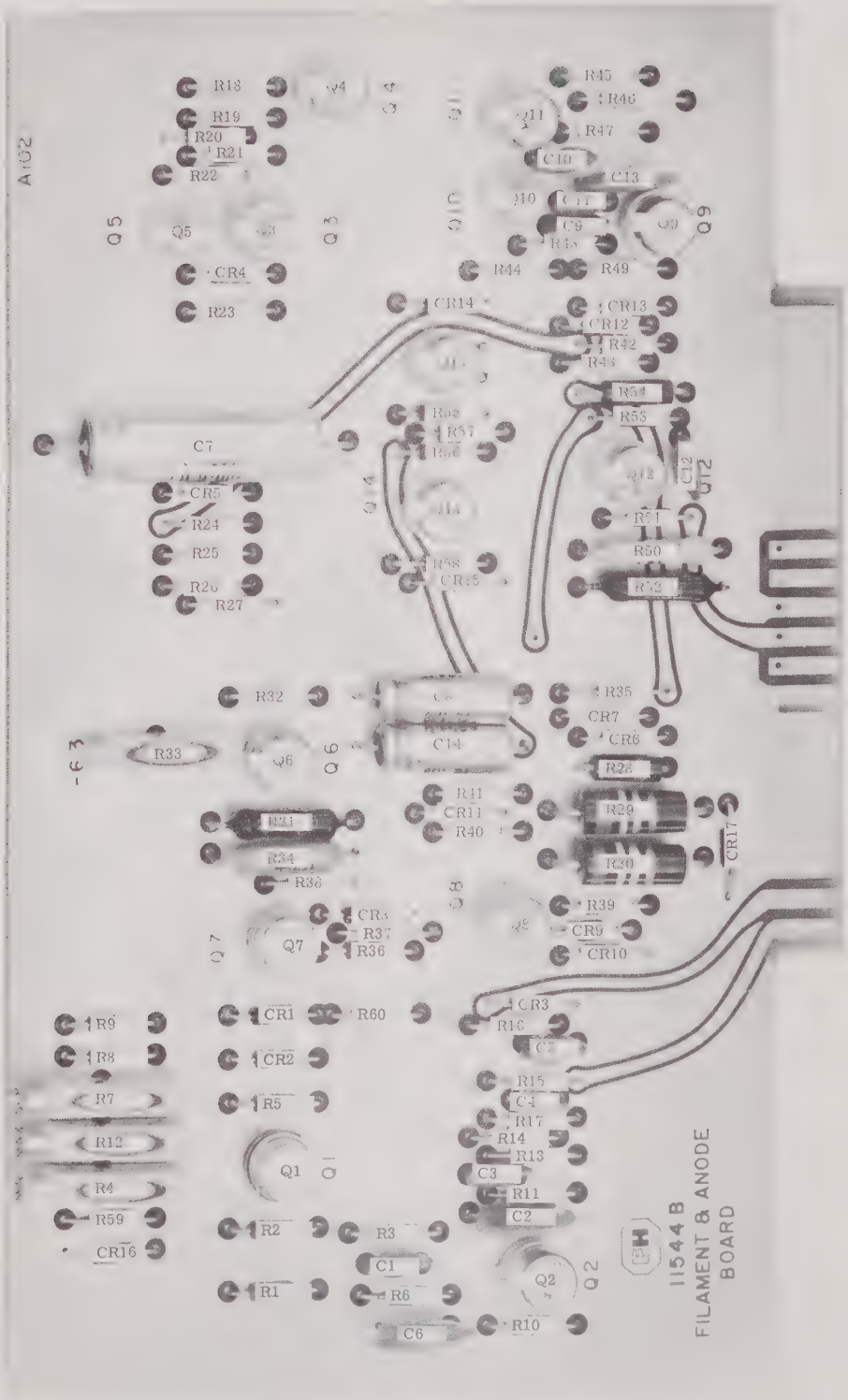


Fig 6-3 A102 Filament and Anode Board

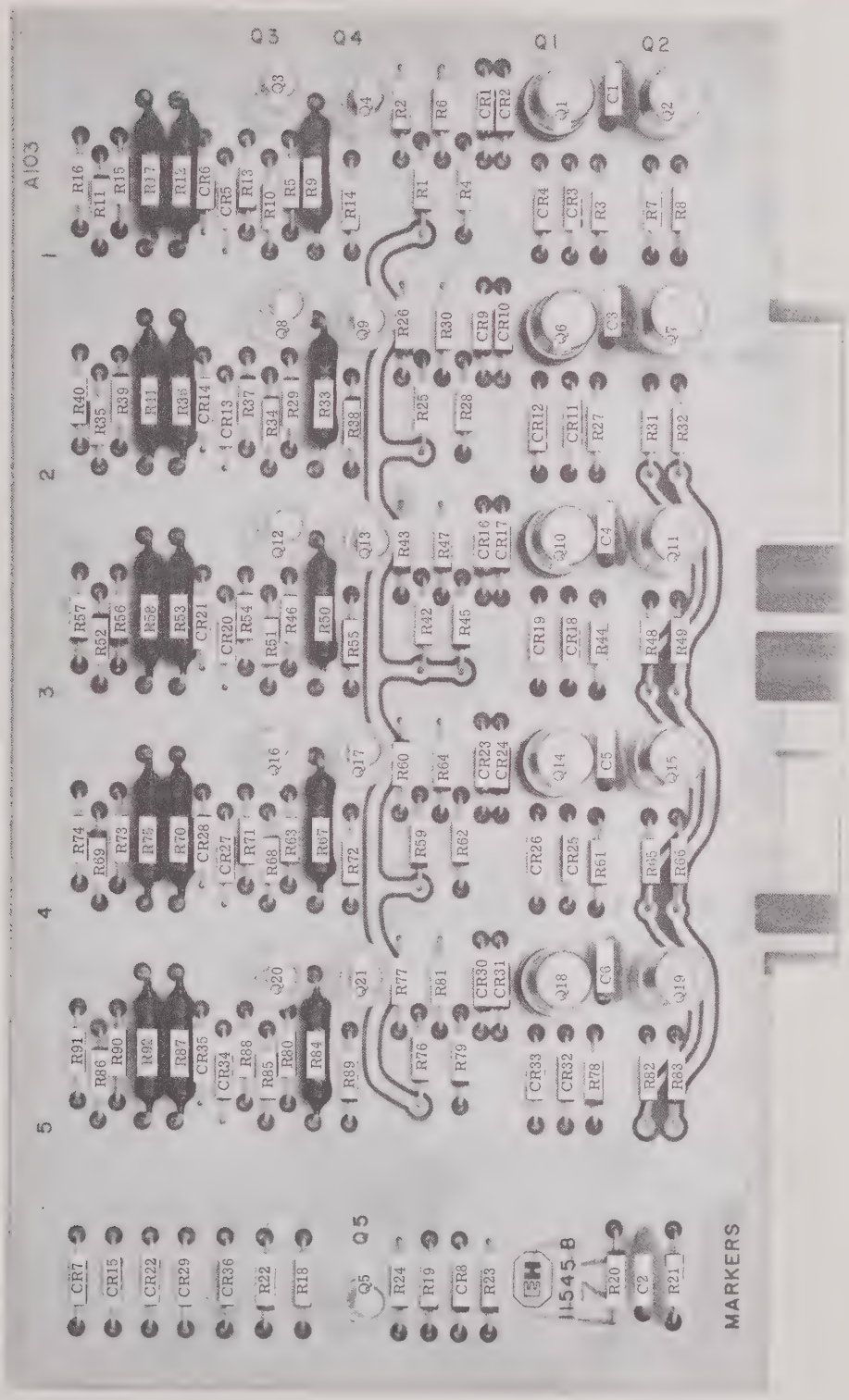


Fig 6-4 A103 Marker Generator Board

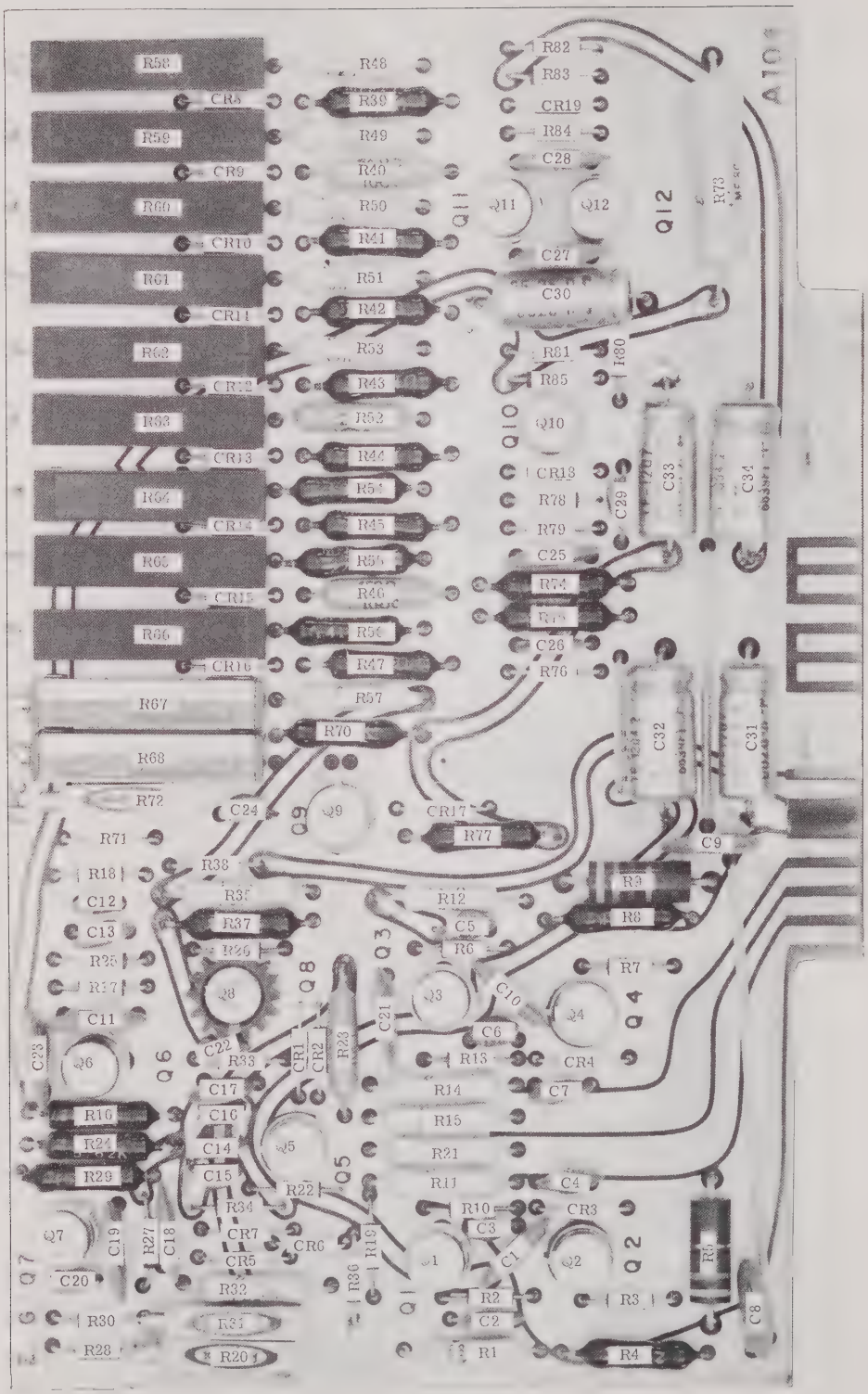


Fig 6-5 A104 Sweep Amplifier Board

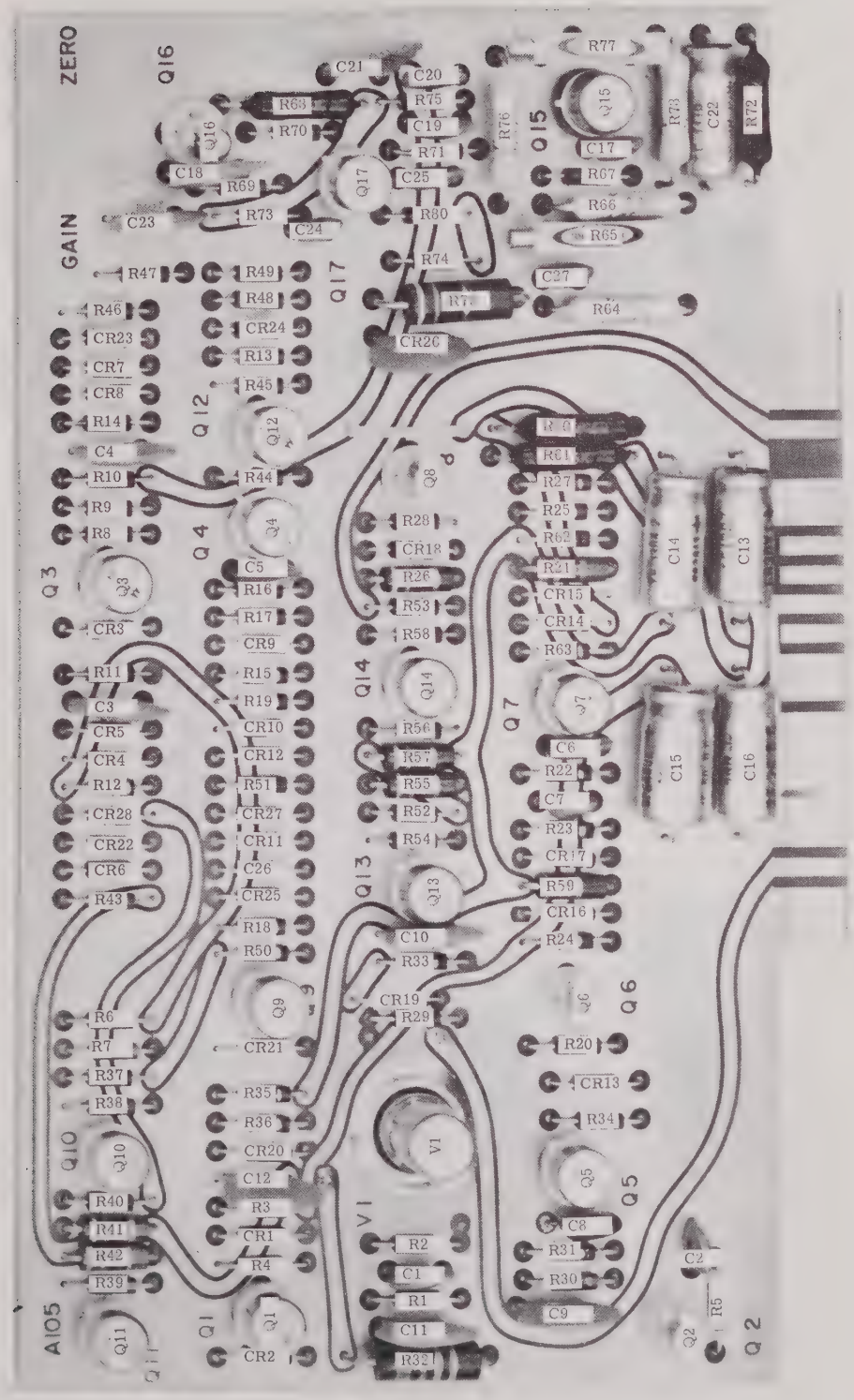


Fig 6-6 A105 Sweep Generator Board

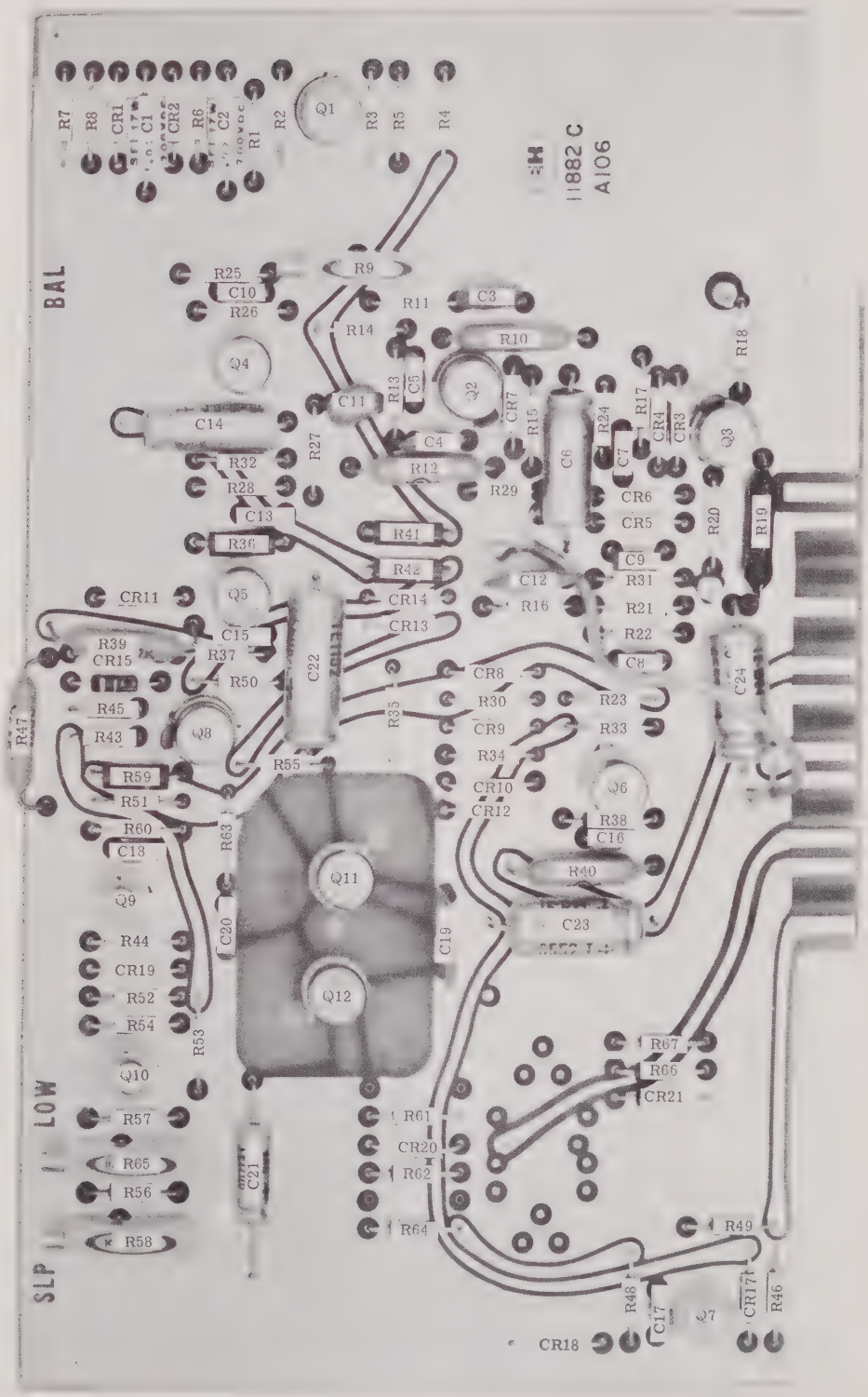


Fig 6-7 A106 Leveler Board for 20 Volt BWO

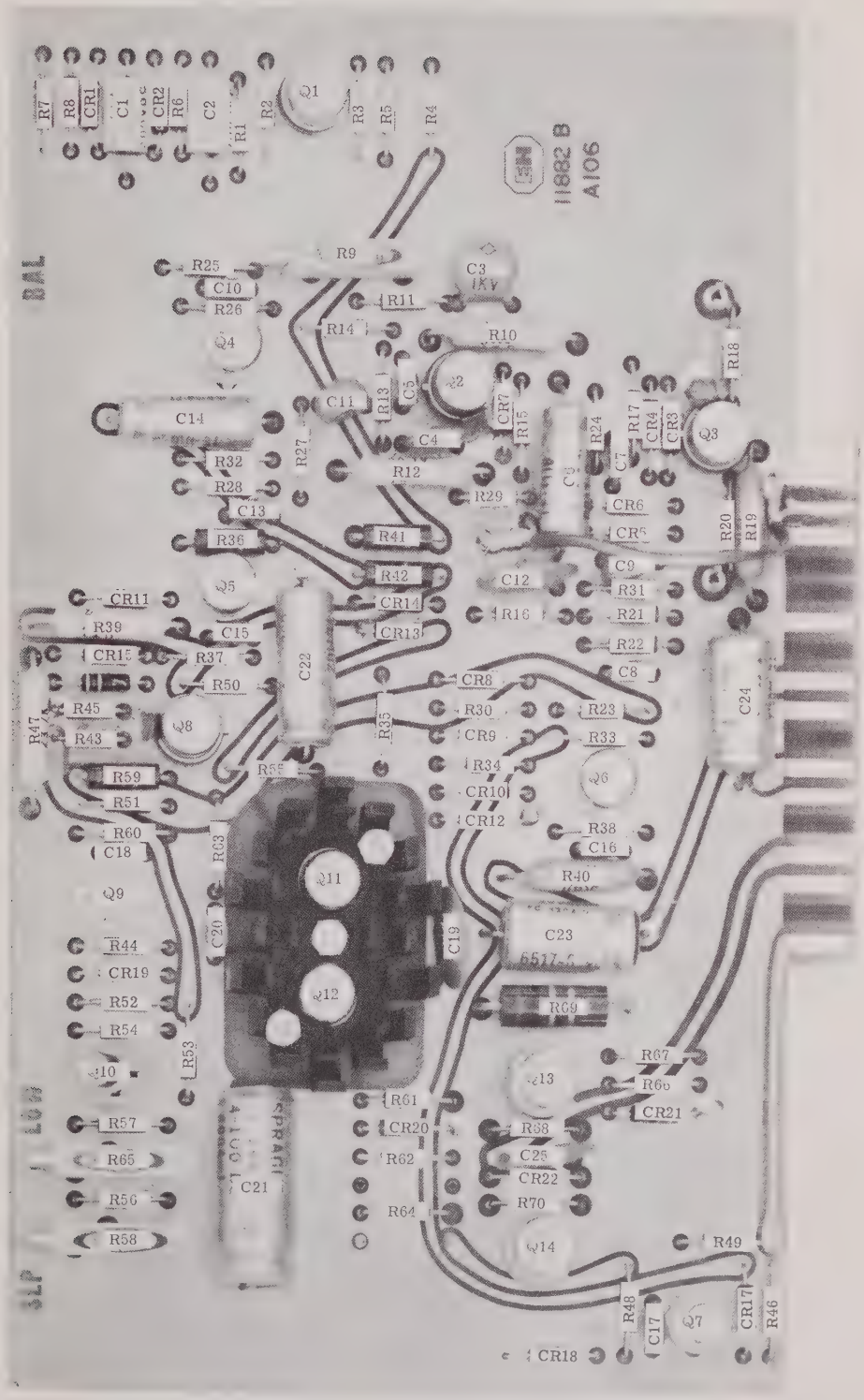


Fig 6-8 A106 Leveler Board for 100 Volt BWO

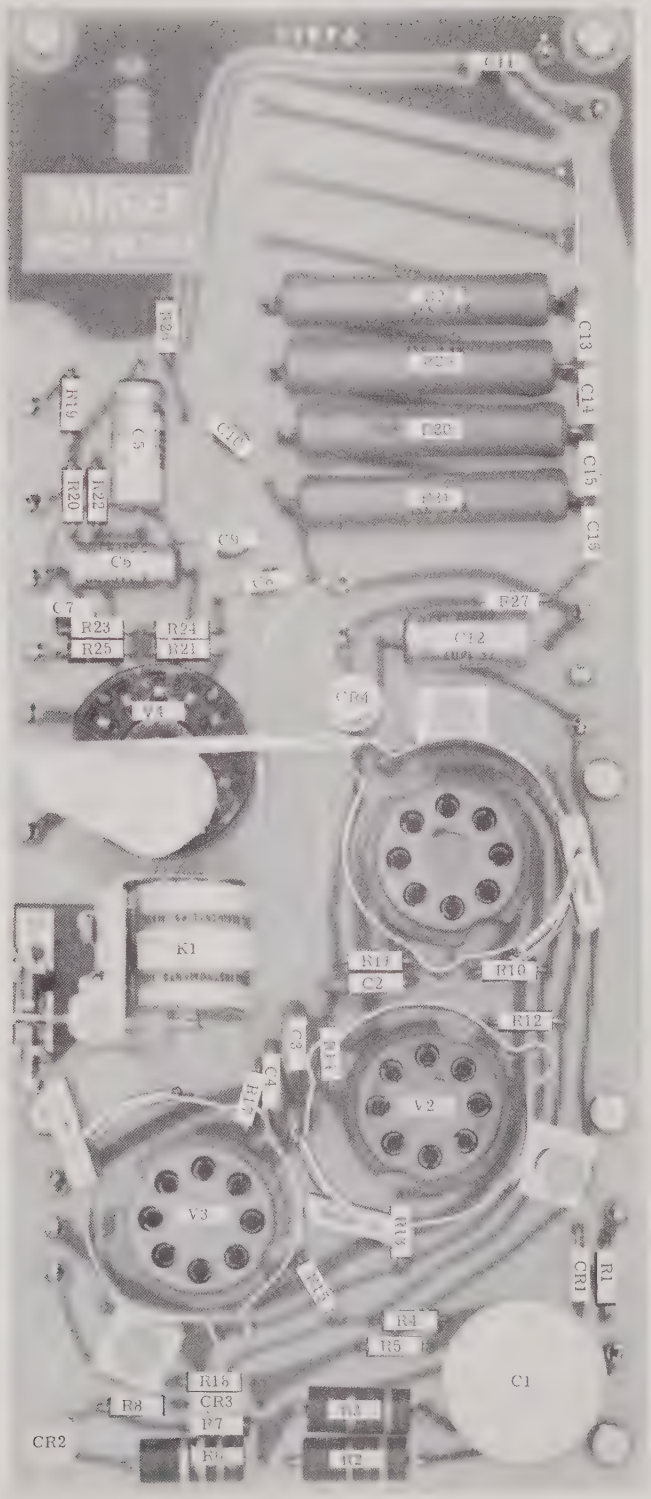


Fig 6-9 Helix Driver Board

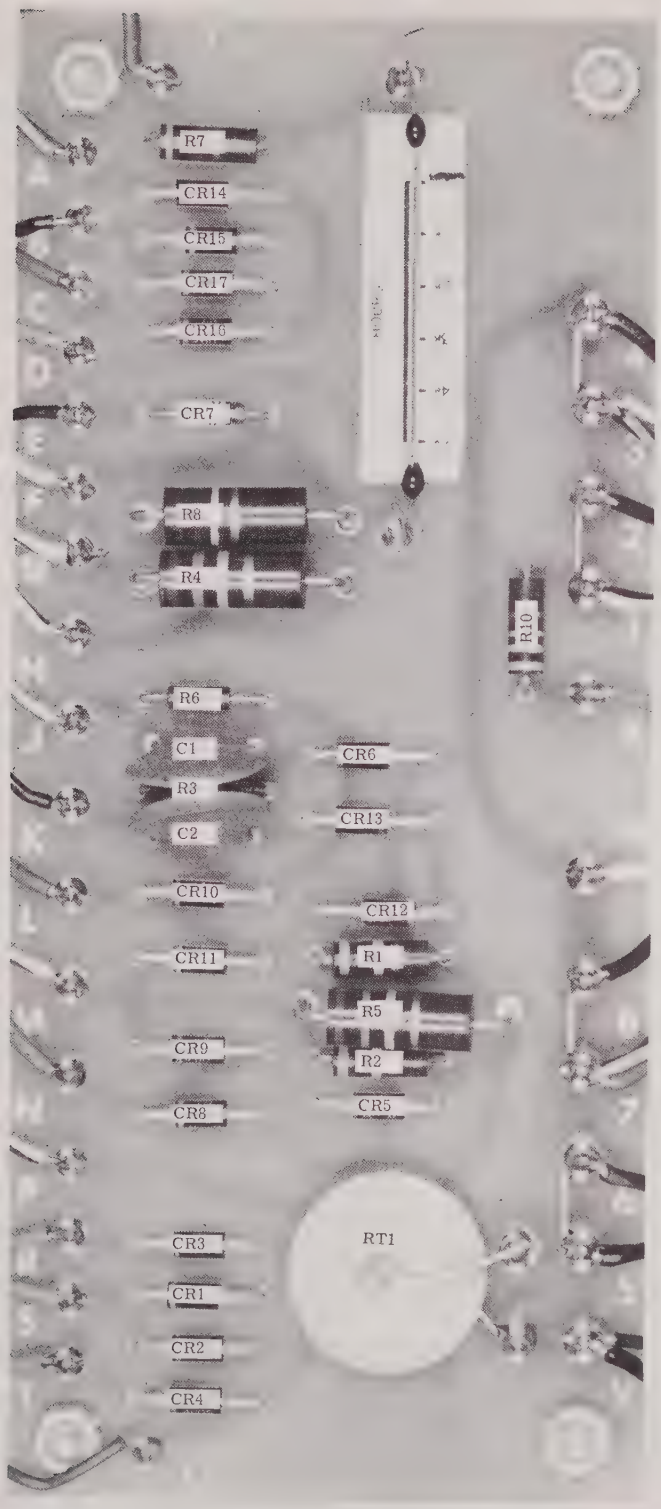


Fig 6-10 Low Voltage Rectifier Board

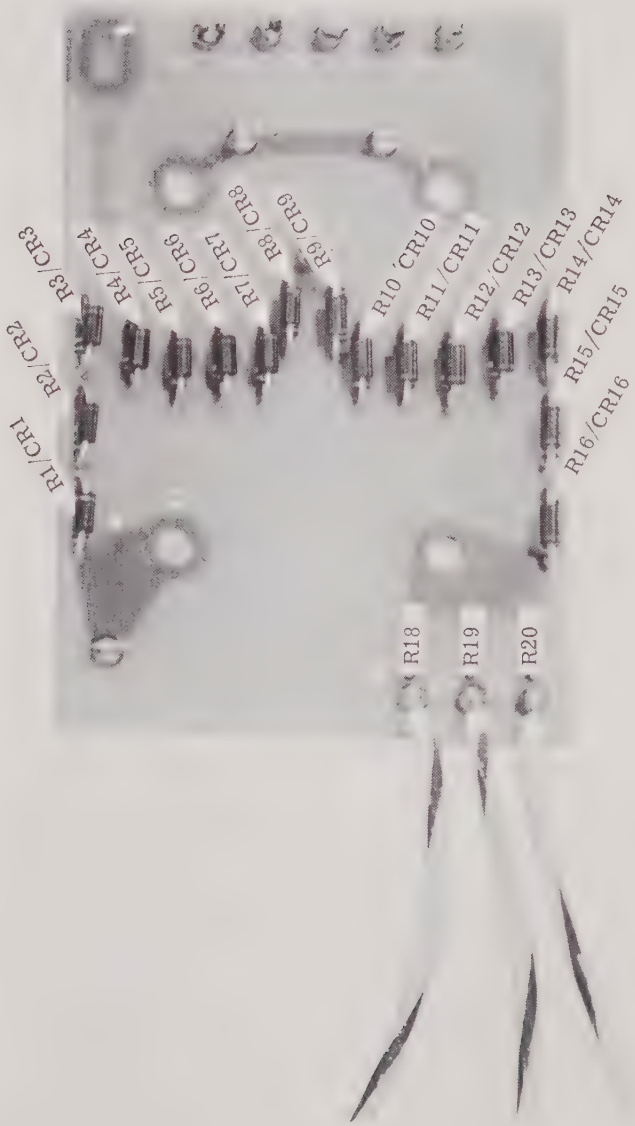
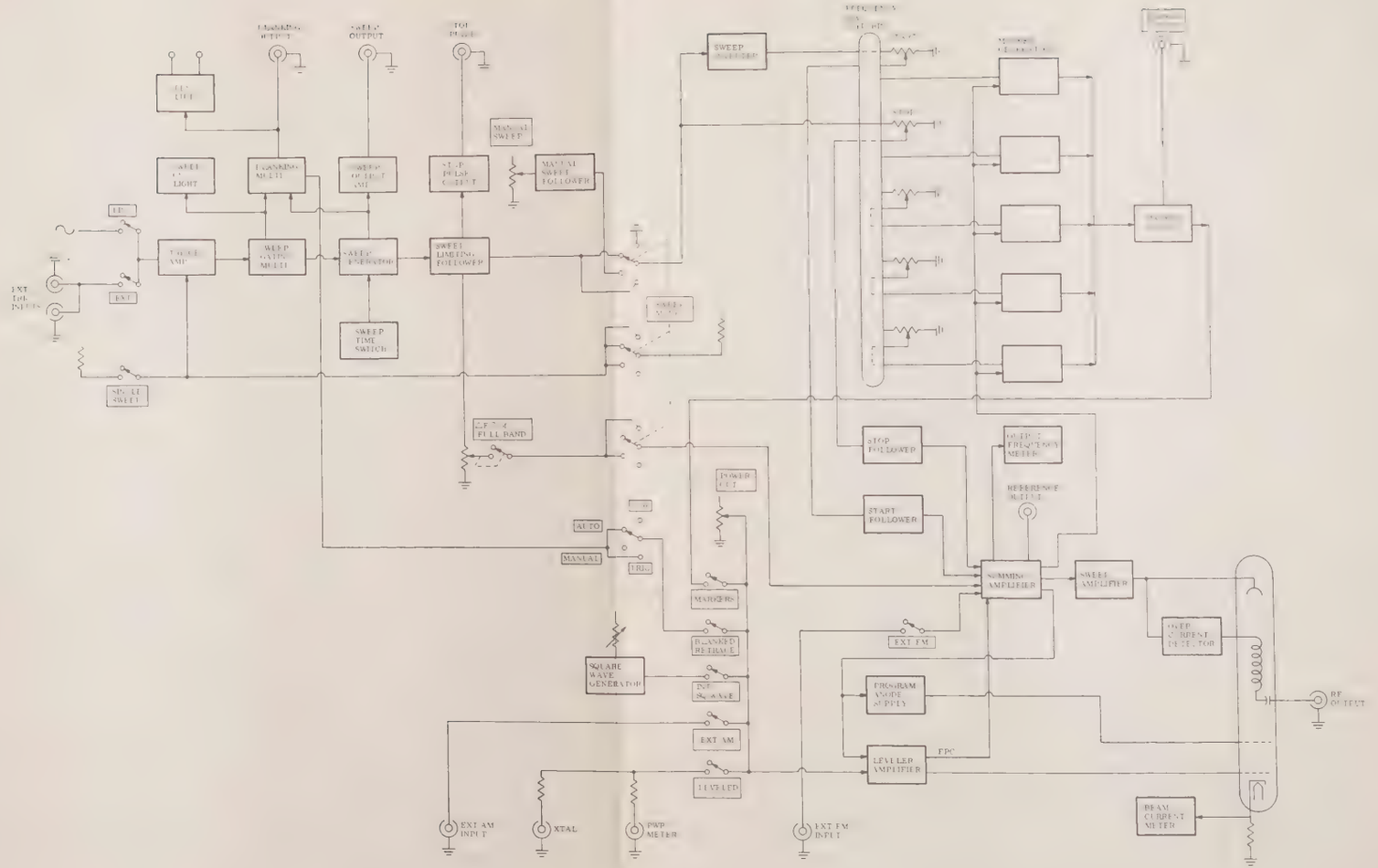
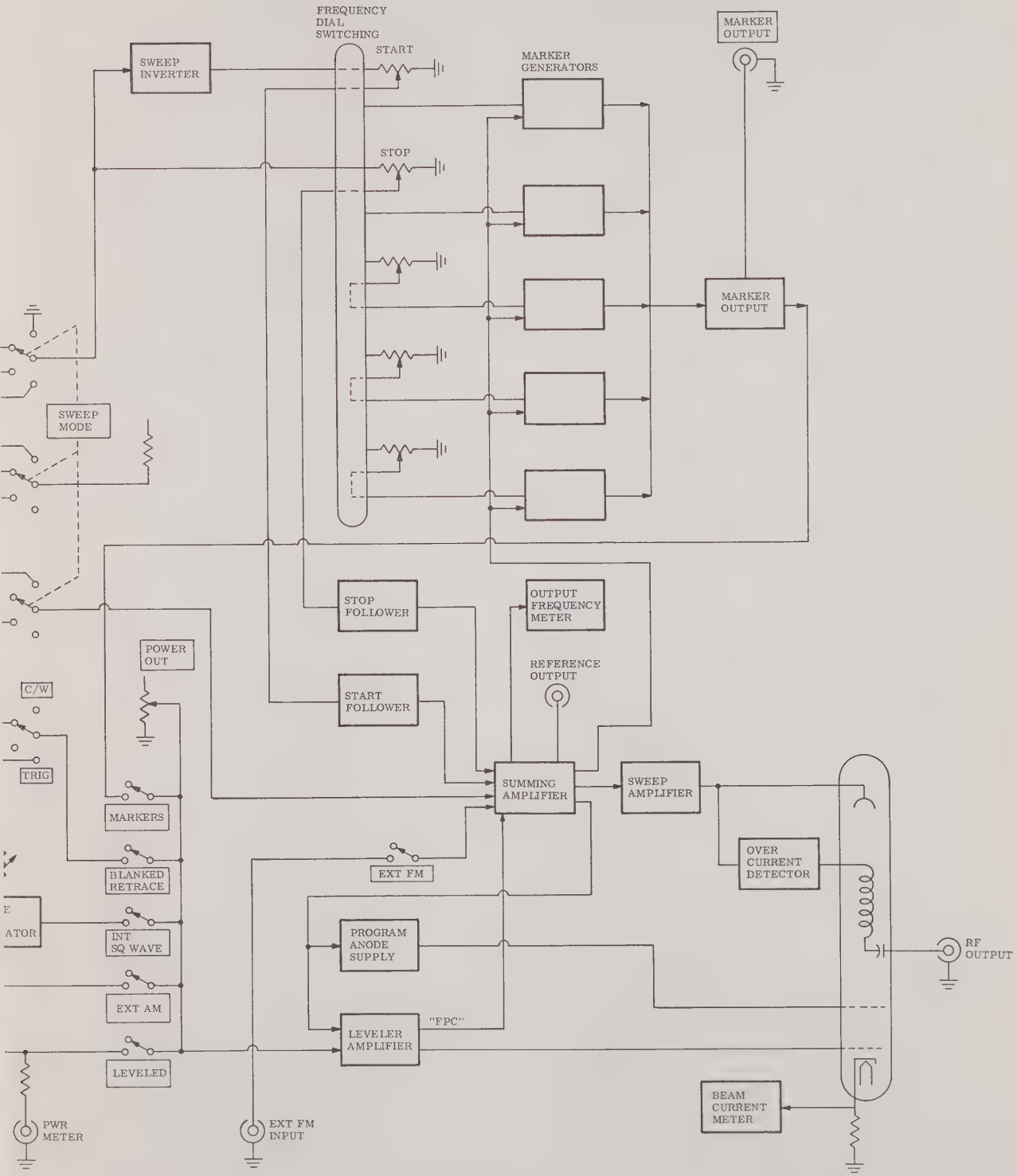


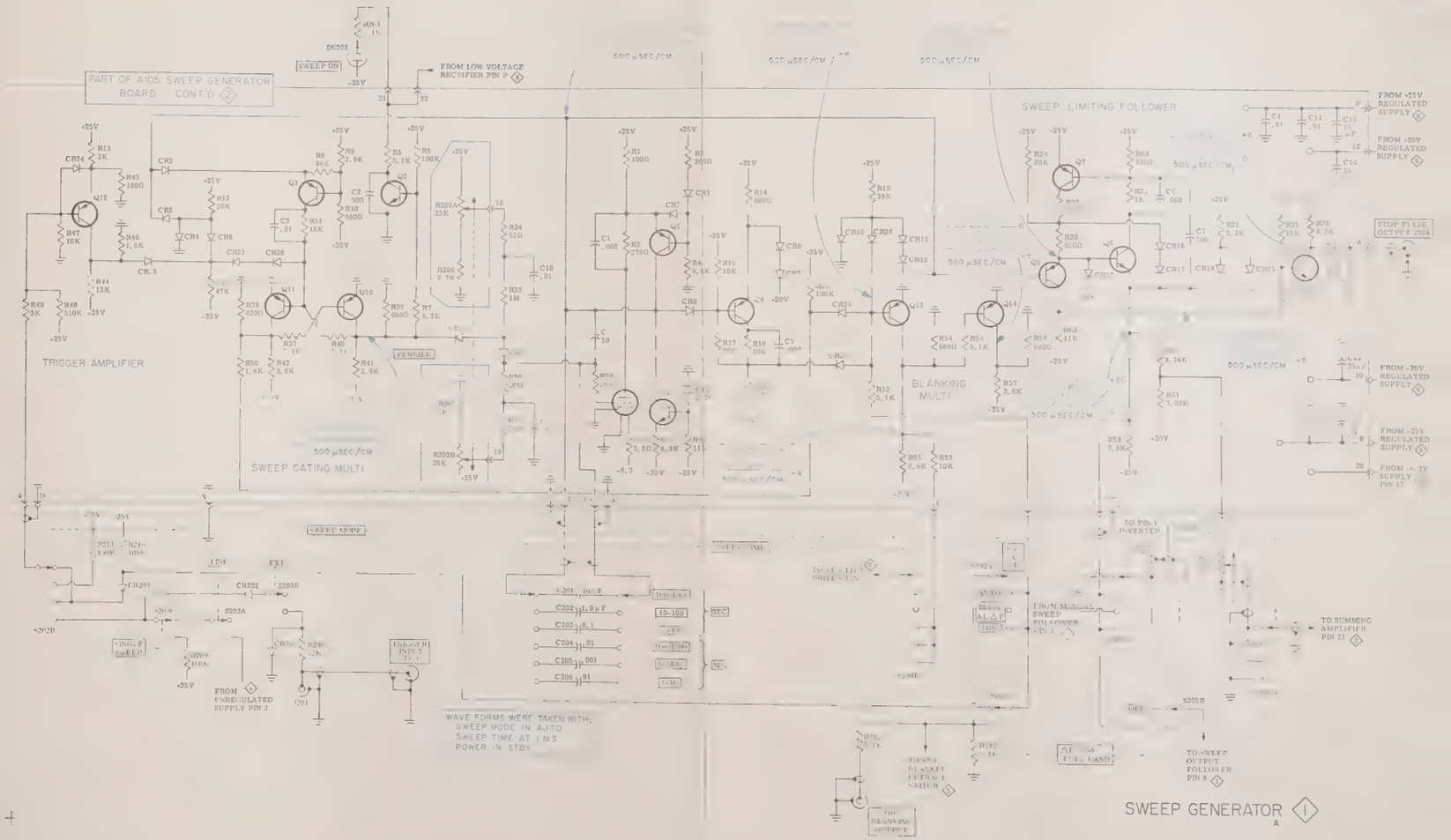
Fig 6-11 High Voltage Rectifier Board

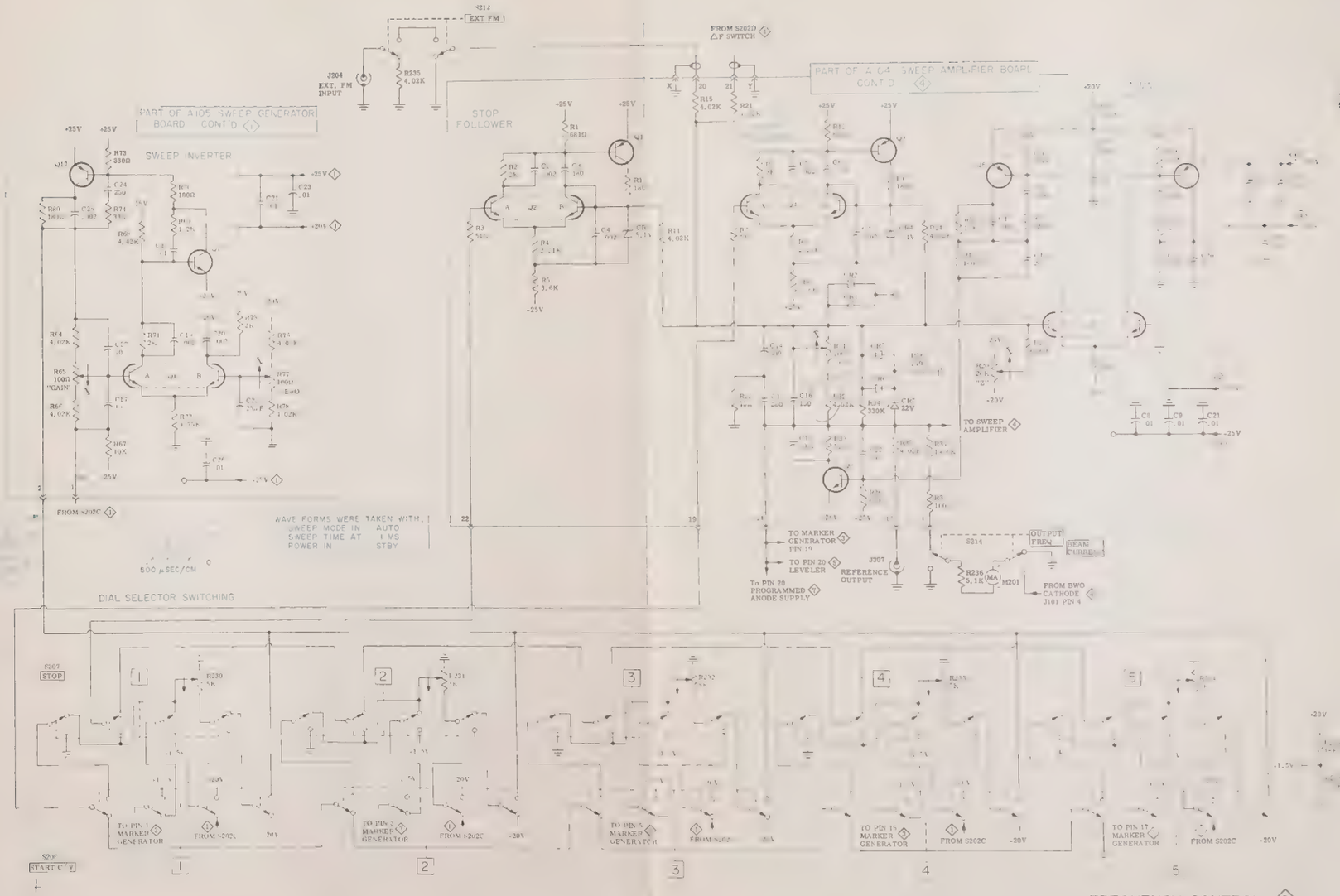


BLOCK DIAGRAM
A

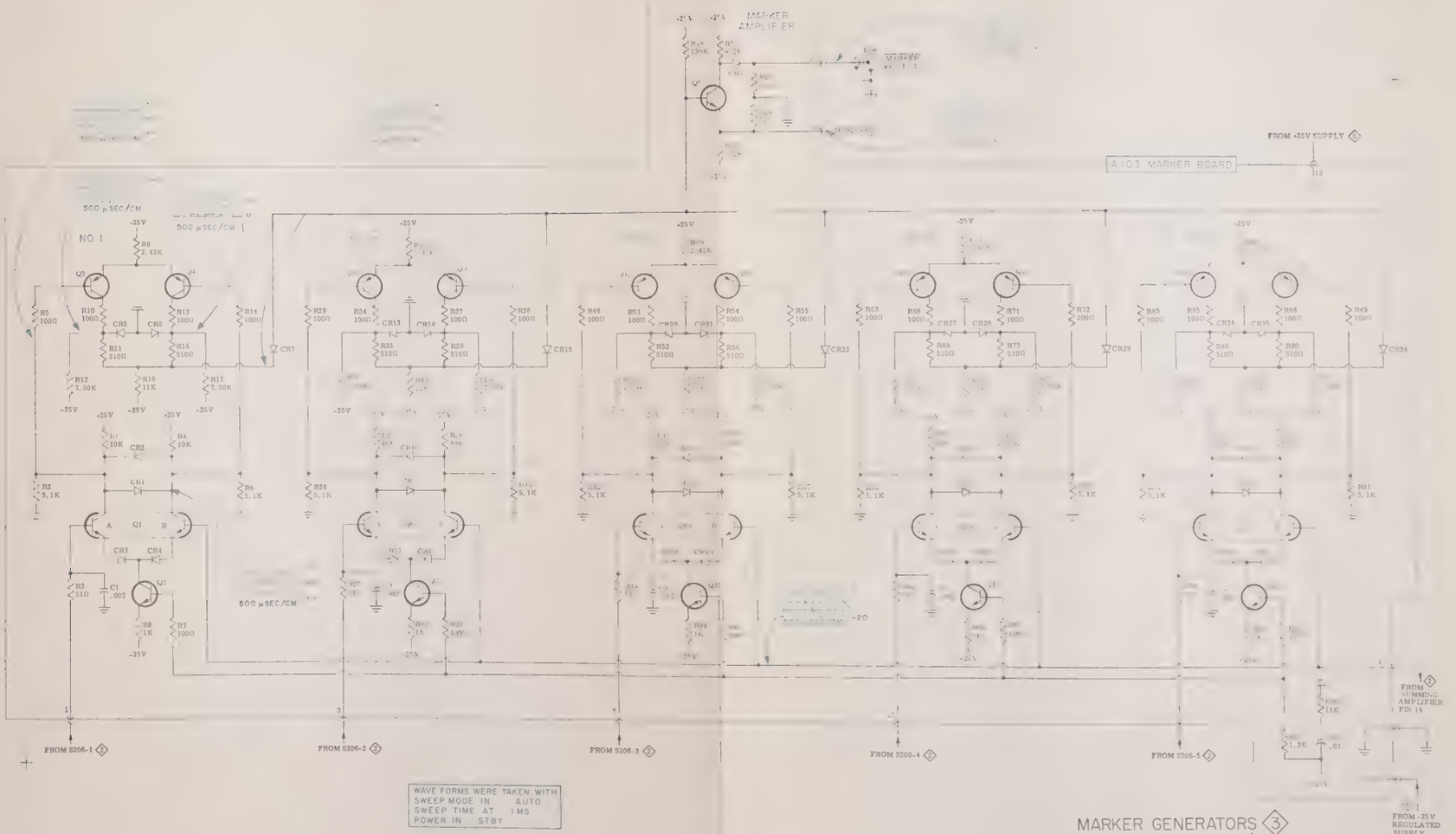


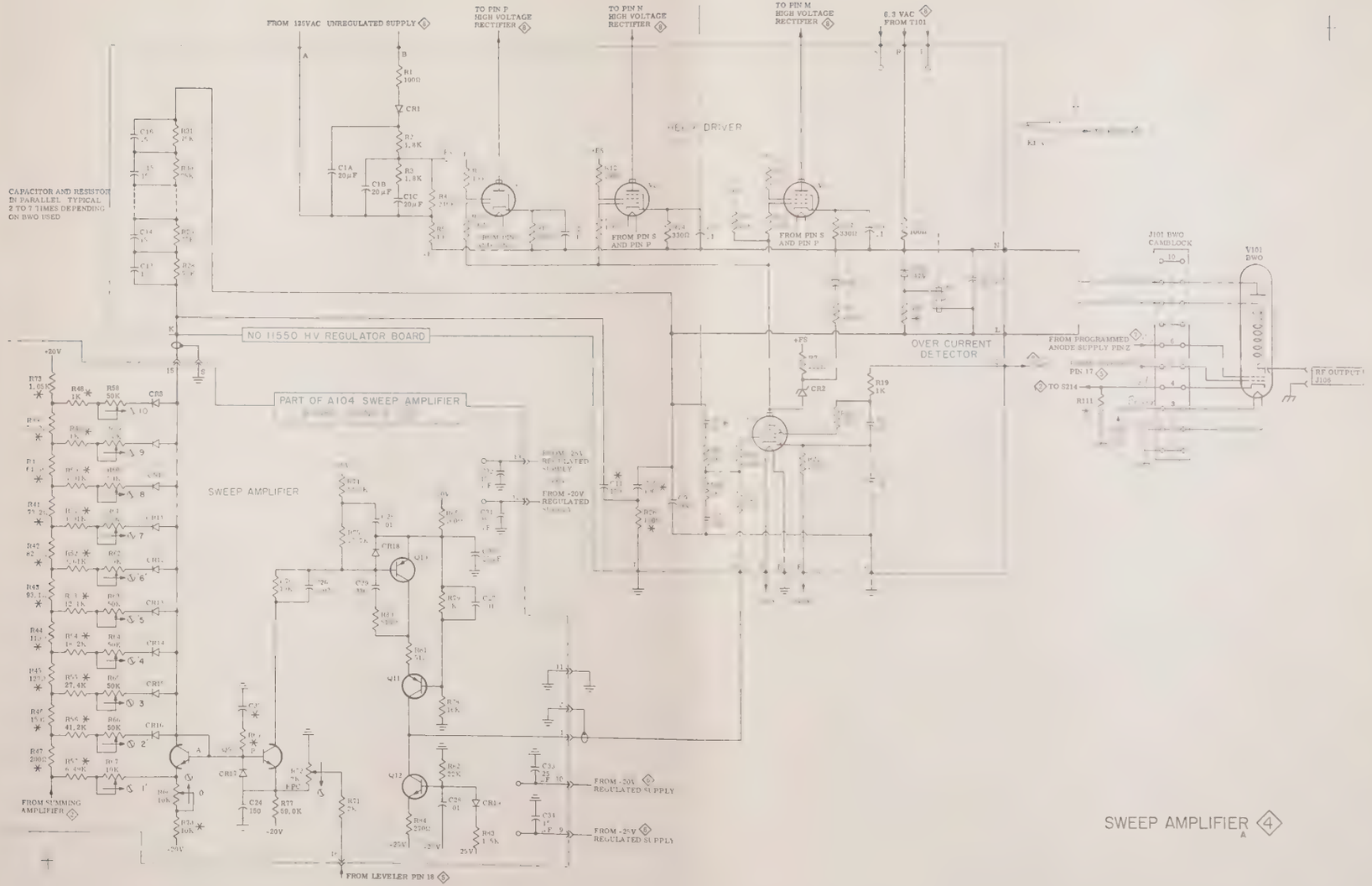
BLOCK DIAGRAM
A


PART OF A10S SWEEP GENERATOR BOARD CONT'D
SWEEP ON
FROM LOW VOLTAGE RECTIFIER PIN P
TRIGGER AMPLIFIER
SWEEP GATING MULTI
BLANKING MULTI
SWEEP LIMITING FOLLOWER
STOP PULSE OUTPUT J304
FROM -25V REGULATED SUPPLY
FROM +20V REGULATED SUPPLY
FROM -20V REGULATED SUPPLY
FROM -22V REGULATED SUPPLY
TO PIN 1 INVERTER
TO SUMMING AMPLIFIER PIN 21
TO SWEEP OUTPUT FOLLOWER PIN 8
FROM UNREGULATED SUPPLY PIN J
WAVE FORMS WERE TAKEN WITH: SWEEP MODE IN AUTO SWEEP TIME AT 1 MS POWER IN STBY
SWEEP GENERATOR A

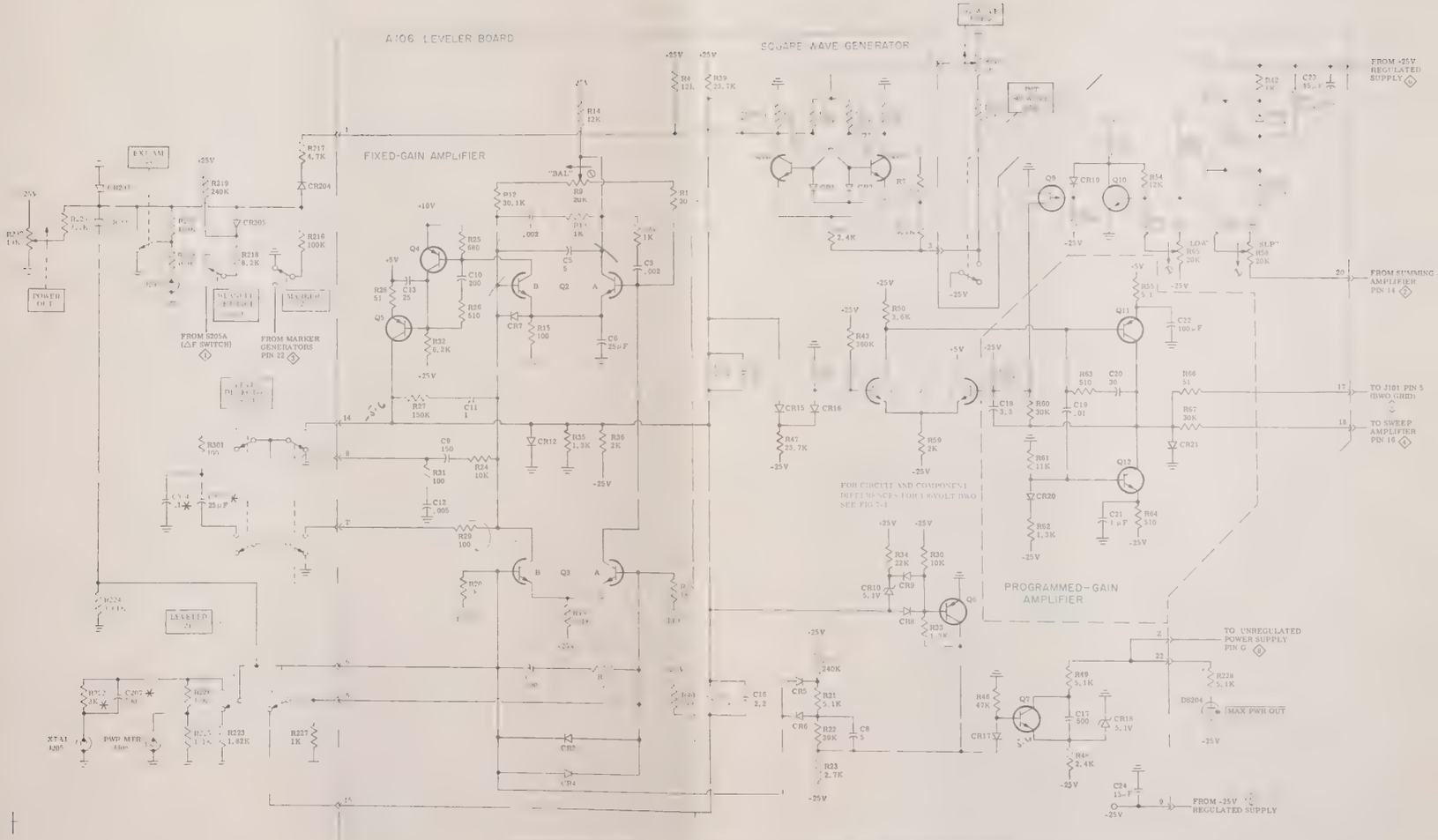


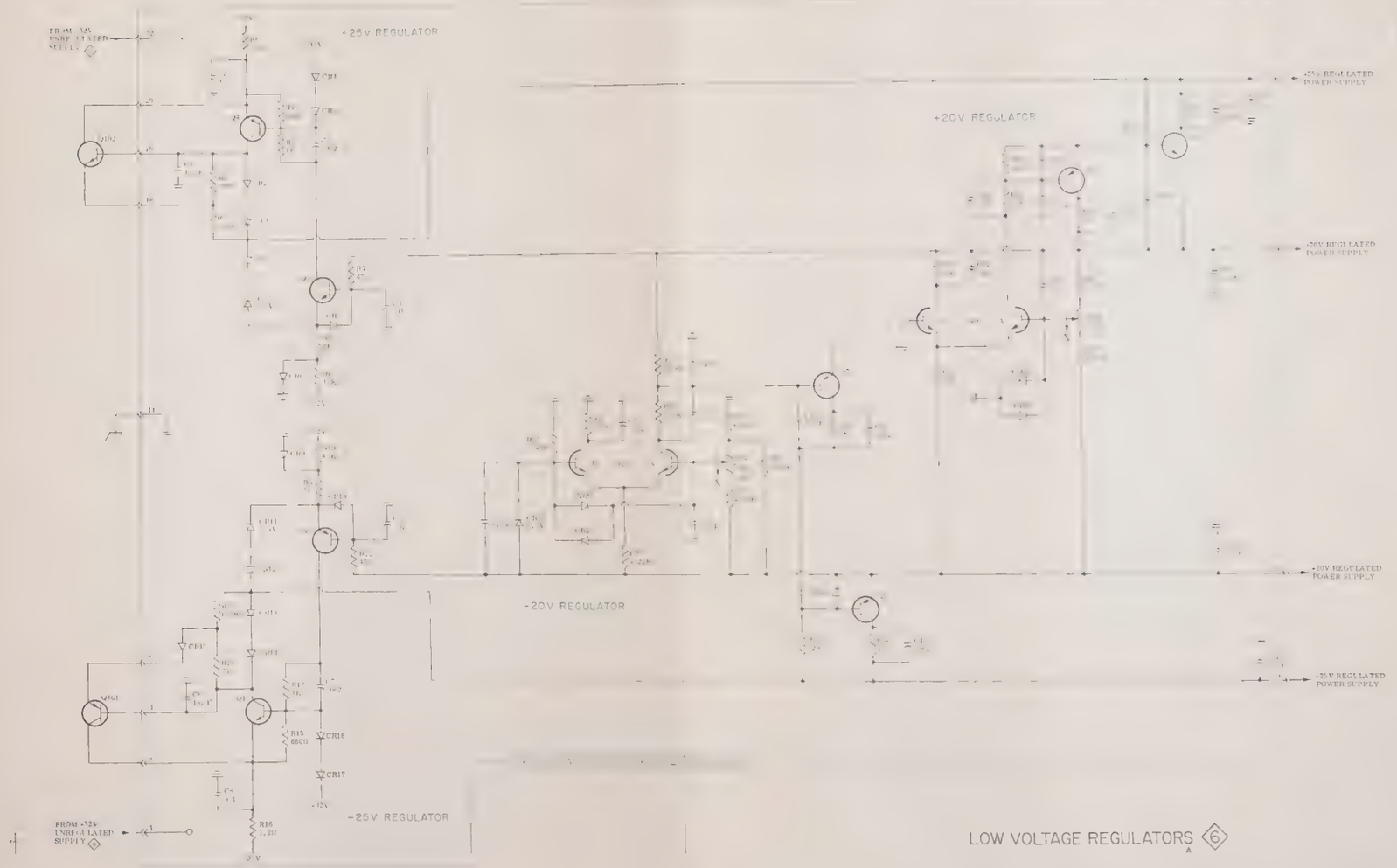
FREQUENCY CONTROL A 2


MARKER AMPLIFIER
FROM +25V SUPPLY
A103 MARKER BOARD
500 μSEC/CM
NO. 1
500 μSEC/CM
500 μSEC/CM
-20
FROM S206-1
FROM S206-2
FROM S206-3
FROM S206-4
FROM S206-5
FROM SUMMING AMPLIFIER PIN 14
FROM -25V REGULATED SUPPLY
WAVE FORMS WERE TAKEN WITH
SWEEP MODE IN AUTO
SWEEP TIME AT 1MS
POWER IN STBY
MARKER GENERATORS
A
3

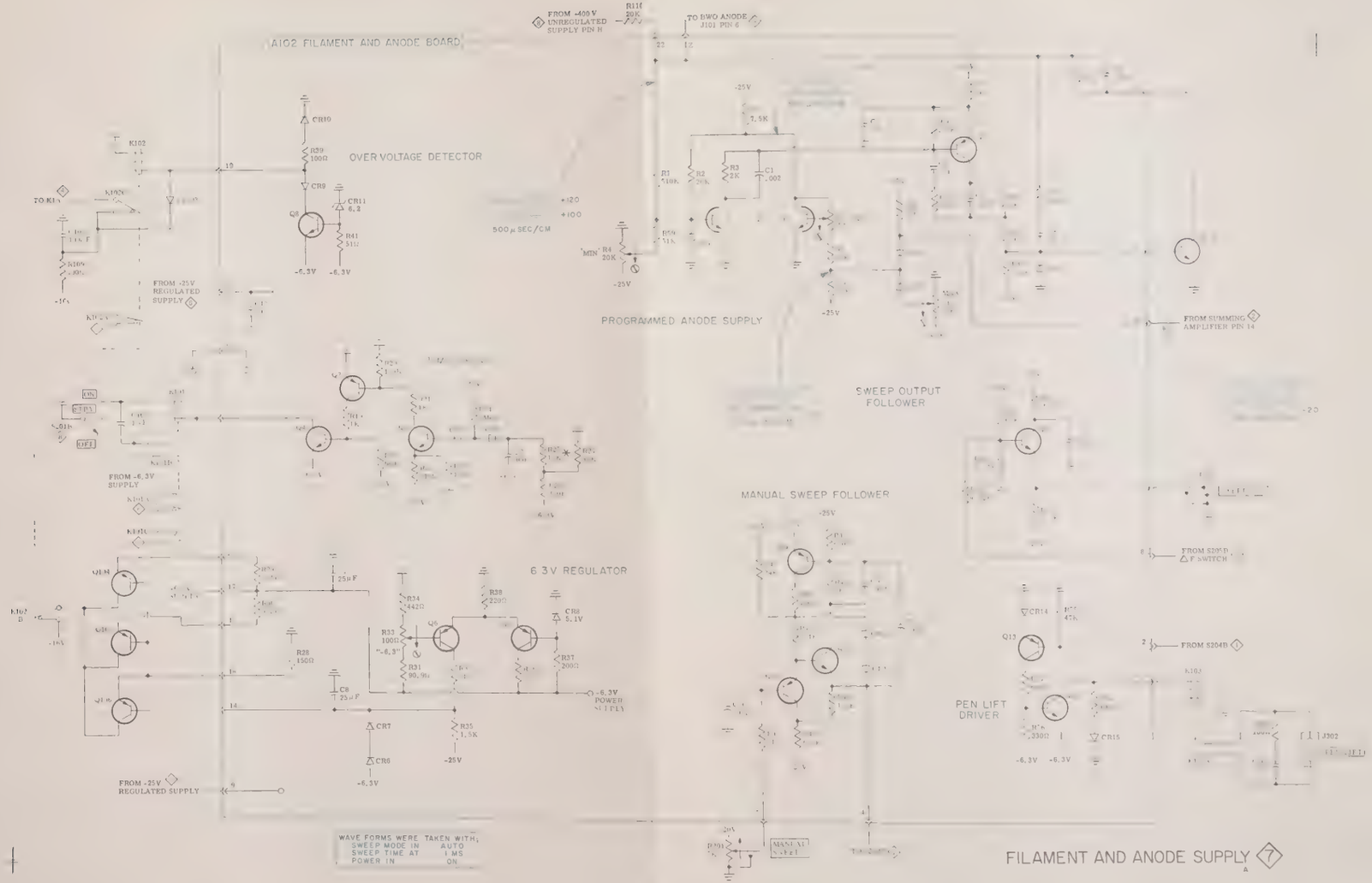


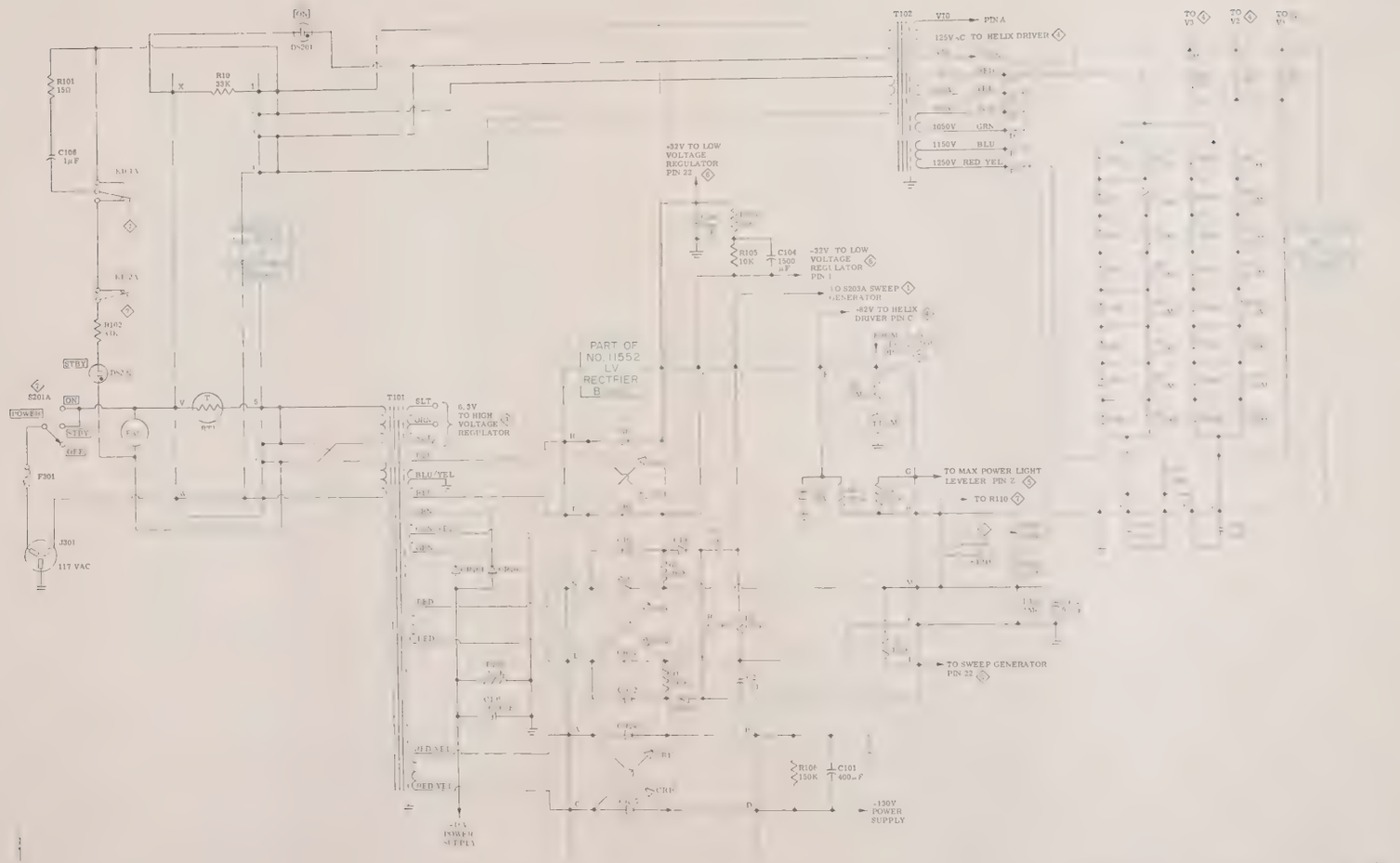
SWEEP AMPLIFIER 4
A


A106 LEVELER BOARD
FIXED-GAIN AMPLIFIER
SQUARE WAVE GENERATOR
PROGRAMMED-GAIN AMPLIFIER
FROM -25V REGULATED SUPPLY
FROM SUMMING AMPLIFIER PIN 14
TO J101 PIN 5 (BWO GRID)
TO SWEEP AMPLIFIER PIN 16
TO UNREGULATED POWER SUPPLY PIN G
FROM -25V REGULATED SUPPLY
FROM S205A (Δ F SWITCH)
FROM MARKER GENERATORS PIN 22
MAX PWR OUT
POWER OUT
EXT AM
LEVELED
PWR MTR
XTAL 1.005
"BAL"
"LO"
"HI"
FOR CIRCUIT AND COMPONENT DIFFERENCES FOR 1 VOLT BWO SEE FIG 5-1



LOW VOLTAGE REGULATORS 6
A


A102 FILAMENT AND ANODE BOARD
OVER VOLTAGE DETECTOR
6.3V REGULATOR
PROGRAMMED ANODE SUPPLY
SWEEP OUTPUT FOLLOWER
MANUAL SWEEP FOLLOWER
PEN LIFT DRIVER
FROM -400V UNREGULATED SUPPLY PIN H
TO BWO ANODE J101 PIN 6
FROM -25V REGULATED SUPPLY
FROM -6.3V SUPPLY
FROM SUMMING AMPLIFIER PIN 14
FROM S205D F SWITCH
FROM S204D
-6.3V POWER SUPPLY
WAVE FORMS WERE TAKEN WITH;
SWEEP MODE IN AUTO
SWEEP TIME AT 1 MS
POWER IN ON
FILAMENT AND ANODE SUPPLY 7



UNREGULATED POWER SUPPLY 8

SECTION 7
CHANGE INFORMATION

The wave-guide type BWOs require 0 to -100 volt drive from the leveler board to the control grid of the BWO. When this type tube is used in the Model 570, the leveler board has two additional transistors, and some of the component values are different to provide the additional grid drive required. Fig 7-1 shows the schematic changes for 100 volt BWO grid drive.

In Section 4, paragraph n4, change "-20" to -100, and change "-5" to -20. Otherwise, the basic information in the remainder of the manual applies to both systems.

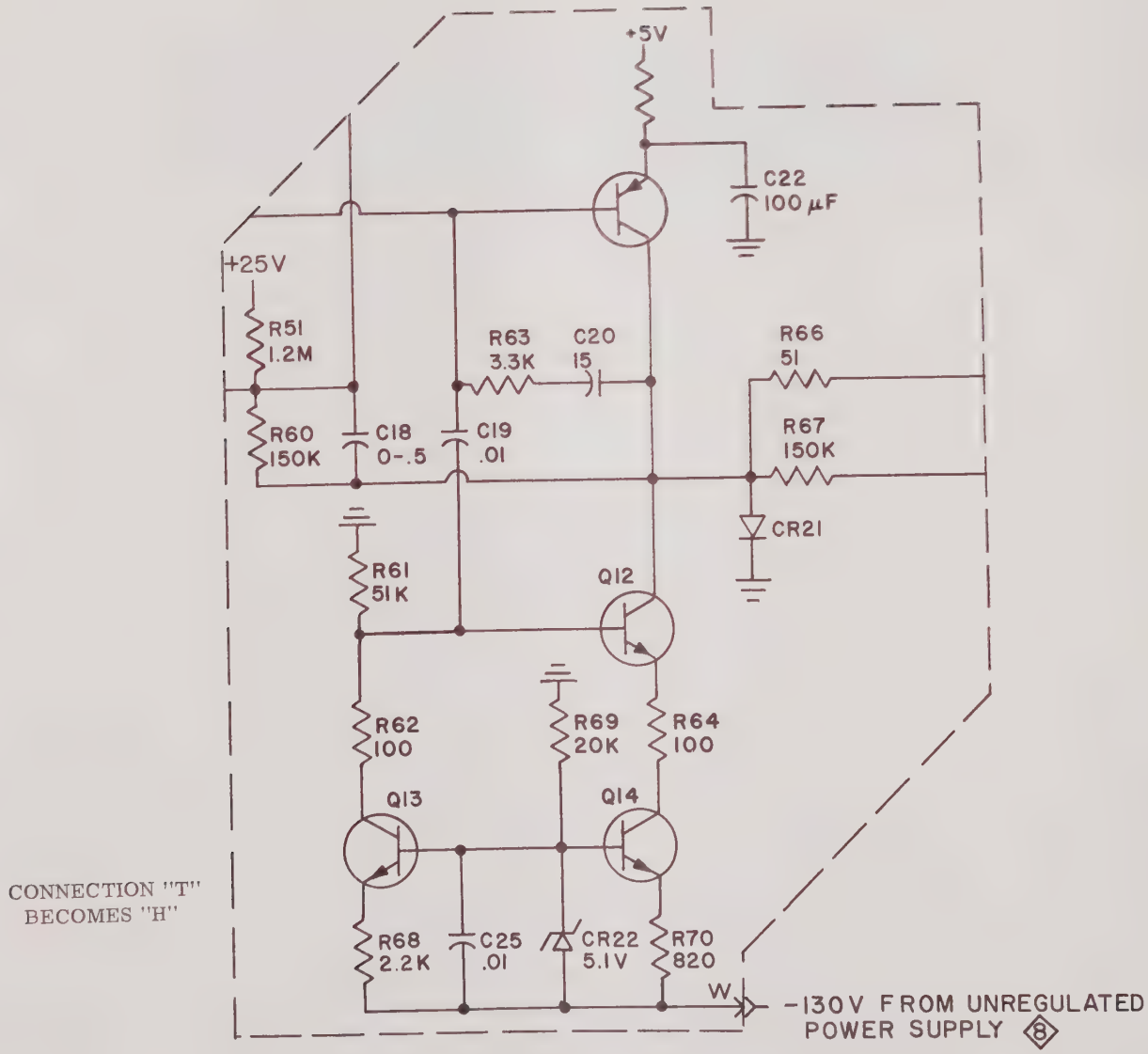


Fig 7-1 Changes to Leveler Board for 100 Volt BWO

WARRANTY CLAIM AND ADJUSTMENT PROCEDURE

for microwave tubes supplied by
E-H RESEARCH LABORATORIES, INC.
for use in E-H instruments

Service centers for E-H instruments are maintained throughout the world. When suspected microwave tube problems arise, do not hesitate to call on your local E-H or representative's office for service assistance.

The procedure described below is for use within the United States. For warranty claims arising outside the U.S.A., before returning the tube, fill out the service information form and send it with a request for shipping instructions to your local E-H office.

Microwave tubes supplied by E-H Research Laboratories, Inc., either as original or replacement, for use in E-H instruments are actually warranted by the tube manufacturer and not by E-H. However, E-H will process warranty claims for you, and will promptly pass on all allowances granted by the tube manufacturer.

In the event that your tube is found to be repairable, the tube manufacturer reserves the right to repair and return the tube in lieu of issuing pro-rata credit.

For your convenience, warranty claims for all microwave tubes supplied by E-H Research Laboratories, Inc. may be made on this single form; merely fill in the information requested and return this form, along with the defective tube, to your E-H field office or to the E-H factory. Please be sure each space on the form is filled in--lack of complete information may delay processing of your claim.

Each tube manufacturer has his own warranty policy. Copies of individual Conditions of Warranty are available from E-H Research Laboratories, Inc.

TUBE RETURN PROCEDURE

NO ALLOWANCE WILL BE MADE FOR RETURNED TUBES WHICH ARE BROKEN ON ARRIVAL AT THE FACTORY. TUBES MUST BE PACKED AND SHIPPED ACCORDING TO THE INSTRUCTIONS BELOW AND THE SERVICE INFORMATION FORM MUST BE PROPERLY COMPLETED AND INCLUDED IN THE TUBE CARTON.

1. Carefully wrap tube in ¼ inch thick "kimpack" cotton batting, or other soft padding material, or "skinpack" on cardboard diagonally fitted into container. Cable assemblies and other accessories not rigidly mounted to the tube should be padded and wrapped separately to prevent damage to the tube during shipment.

2. Wrap the above in heavy kraft paper.

3. Pack in a rigid container which is at least 4 inches larger than the tube in each dimension.

4. Surround the tube with at least 2 inches of packed excelsior or similar shock absorbing material. Be certain that the packing is tight all around the tube.

5. Tubes returned from outside the continental United States should be packaged in a wooden box.

6. Mark container fragile and ship prepaid via air freight or railway express to address shown on the opposite page. Do not ship via parcel post or air parcel post.

N O T E

Tubes with permanent magnets can interfere with magnetic compasses. For air shipment plainly mark container: "MAGNETIZED MATERIAL"

MICROWAVE TUBE WARRANTY CLAIM

SERVICE INFORMATION FORM

IMPORTANT: Please answer all questions fully -- insufficient information will delay processing of your claim. Note tube return procedure on reverse side.

DATE_____

FROM: (TUBE OWNER)

COMPANY_____

ADDRESS_____

_____

TUBE MANUFACTURER_____

_____

TUBE TYPE_____

TUBE SERIAL NO._____

TUBE IS ORIGINAL ( )

TUBE IS REPLACEMENT ( )

DATE TUBE RECEIVED_____

DATE FIRST TESTED_____

DATE PLACED IN SERVICE_____

FOR FURTHER INFORMATION CONTACT:

NAME_____

TITLE_____

COMPANY_____

ADDRESS_____

_____

E-H MODEL NO._____

INSTRUMENT SERIAL NO._____

EQUIPMENT PURCHASE DATE_____

HOURS USE PER DAY (average)_____

NUMBER OF DAYS IN SERVICE_____

ELAPSED-TIME METER READING_____

or ESTIMATED TOTAL FILAMENT HOURS_____

DATE OF FAILURE_____

SYMPTOMS: (Please describe conditions prior to and at time of failure, along with description of the tube's defect, if known.)

_____

_____

Please describe any other circuit component failures which occurred at the same time

_____

_____

SIGNATURE_____

TITLE_____

TUBES RETURNED TO E-H SHOULD BE ADDRESSED TO:

CUSTOMER SERVICE DEPARTMENT, E-H RESEARCH LABORATORIES, INC.

163 ADELINE STREET, OAKLAND, CALIFORNIA - Phone: TE 4-3030, Area Code 415

TWX: 910-336-7258

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